Targets

#		Country
1	🇺🇸	United States
2	🇩🇪	Germany
3	🇳🇱	Netherlands
4	🇬🇧	United Kingdom
5	🇨🇭	Switzerland
6	🇧🇪	Belgium

Origins

#		Country
1	🇨🇳	China
2	🇷🇺	Russia
3	🇺🇸	United States
4	🇺🇦	Ukraine
5	🇮🇳	India
6	🇹🇭	Thailand

Innovating in Cyber Security

Shared research 2019

CELEBRATING 5 YEARS OF DUTCH CYBER SECURITY INNOVATION

ABN·AMRO achmea ING Rabobank de volksbank TNO innovation for life

Contents

Preface

This is the second edition of the magazine produced by the Dutch Cyber Security Shared Research Program (SRP), a collaboration involving TNO, ING, ABN AMRO, Rabobank, Volksbank and Achmea and which is financially supported by the Dutch government. This magazine serves two purposes;

- to share our experience that cooperation in a Shared Research Program adds value for every participant;
- to share some of the results that have been achieved in this Program in the previous two years.

We hope these experiences and results again will offer you some fresh perspectives on cyber security innovation, which we believe is essential to maintain a robust and safe society.

The projects and the results highlighted in the magazine prove the added value of cooperation, which is the basis for this Program and is a common theme that returns in the articles in the magazine. As in the first edition, throughout the magazine, security leaders from each of the partners involved in this SRP share their views on cooperation within the Program, and on the resultant benefits.

In 2019, the SRP celebrates its five year anniversary. We will continue the cooperation in the coming years and foster new partnerships.

We trust that the experiences and results presented in this magazine will benefit individual organisations and trigger them to explore new ways of defending against cyber-attacks, resulting in a safer Dutch society as a whole.

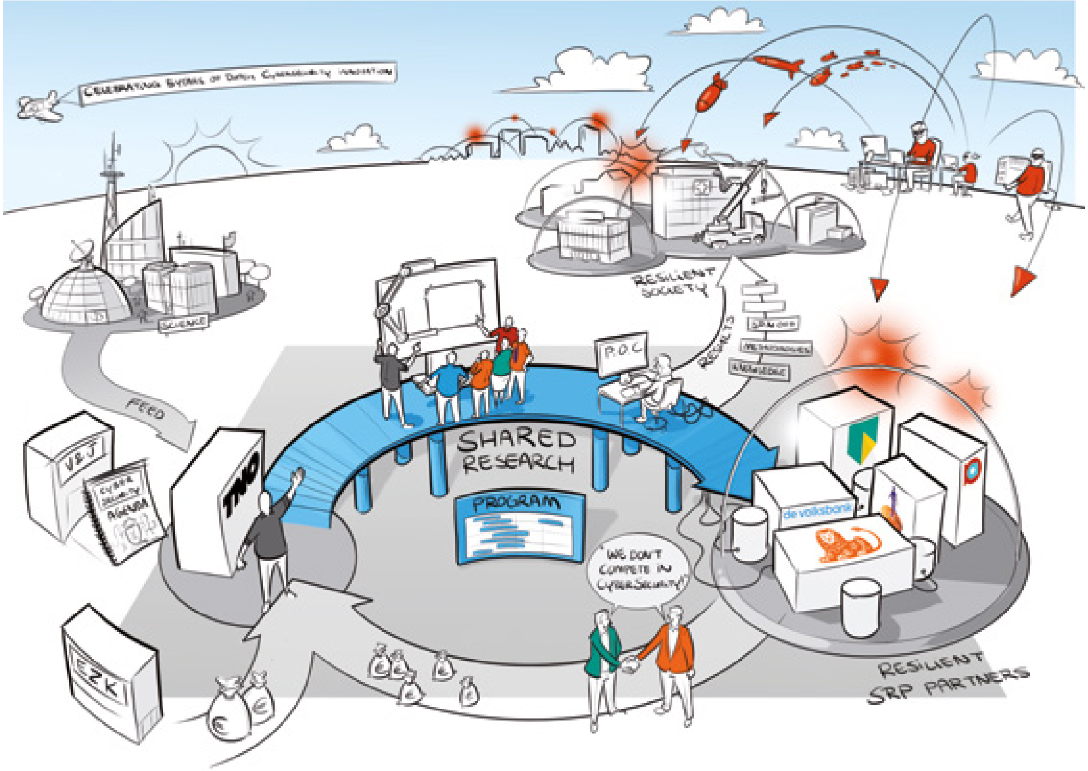
Enjoy reading the magazine!

Olaf Streutker (ABN AMRO)
Tom Huitema (Achmea)
Ruud Zwan (ING)
Henny van der Pavert (Rabobank)
Mark Buningh (TNO)
Reinder Wolthuis (TNO)
Rob van Os (Volksbank)

Shared Research Program Cyber security - introduction

Author: Reinder Wolthuis (TNO)

2019 marks the five-year anniversary of successful cooperation in the Shared Research Program Cyber Security.



The overall umbrella of the articles in this magazine is the Shared Research Program (SRP) Cyber Security. The partners in the SRP cooperate to improve cyber security by means of innovation in various technologies and processes. The overall goal is to improve the prevention and detection of cyber-attacks (and the subsequent recovery) by developing a range of innovative technologies and methods. This development work will draw on the participants' expertise in the areas of security technologies and methodologies, data analytics, incident and crisis management, and behavioural sciences. The SRP partners benefit by applying newly developed methodologies and tools that instantaneously improve their ability to control cyber security threats. But they also can use the built-up knowledge and results of proof-of-concepts to make well-informed decisions on investments and future security strategy.

ABN AMRO, ING, Rabobank and TNO started the SRP in 2014, so 2019 marks the five-year anniversary of this successful cooperation. During these five years, we were joined by Achmea and Volksbank, making the current number of partners six. We are still open for new partners, including partners from other (non-financial) sectors, that want to cooperate in cyber security innovation.

The foundation of the cooperation model lies in three aspects:

- Shared workload – while the program's project teams are primarily made up of TNO staff, these are complemented with staff members from each of the participating partners; they actually participate in and contribute to the projects, making each project team a valuable combination of research oriented staff and staff that has a more practical (operational) perspective. An interesting effect also is that staff of participating financial institutions has a chance to meet in a completely different context, and we have seen some fruitful follow-up activities outside the SRP of these meetings.

- Shared data – the participating partners provide anonymized, real-life data to evaluate innovative security methods, thereby enhancing the evaluation results and increase the value of the project output.
- Shared funding – the costs of the SRP are shared between partners, with contributions of each individual partner, on top of the in-kind contributions. The Dutch government also provides funding.

The SRP aims to conduct ‘applied research’ (see Figure 1). This means that the SRP’s research activities use scientific knowledge as input, and deliver knowledge that is ready for product & service development. In a selection of projects, the research activities involved are more oriented towards long-term goals.

The current Roadmap is depicted in Figure 2.

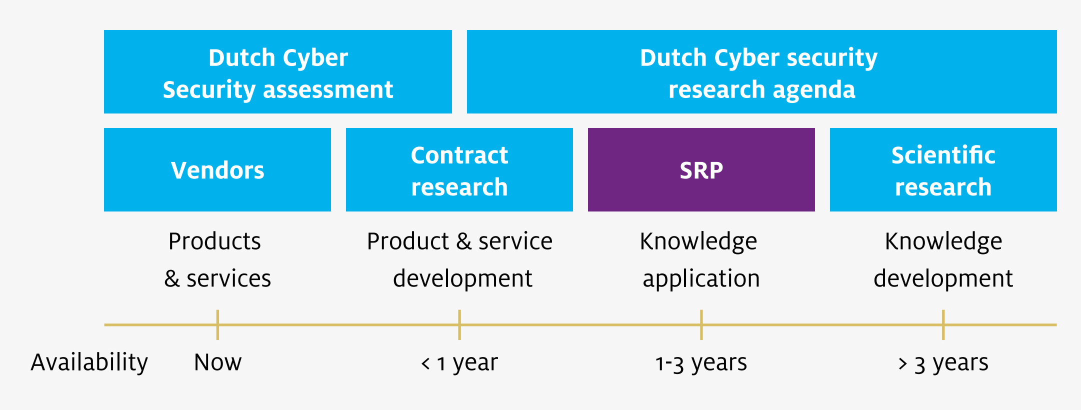


Figure 1: SRP in the wider context of cyber security research

The SRP team of Volksbank, that joined ithe program in 2018.

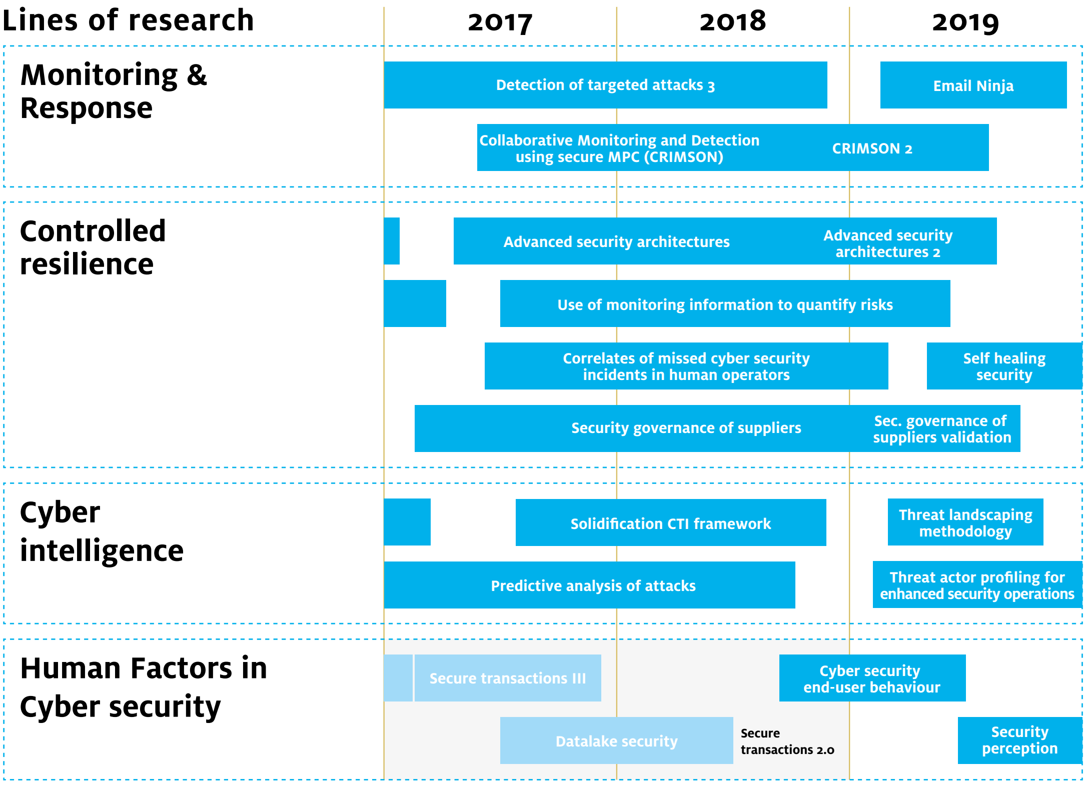


Figure 2: Current Roadmap of the Shared Research Program Cybersecurity

> Results achieved in the SRP Cyber Security are often made public, so the Dutch society can enhance its Cyber Resilience posture.

We have organized the SRP in four lines of research:

- Monitoring & Response – the aim is to improve the monitoring of (and response to) cyber security incidents, through innovation in monitoring and response technologies and processes.
- Controlled Resilience – the aim is to improve organizations' cyber resilience, through innovation in resilience technologies and processes. Cyber resilience is defined as an organization's ability to cope with cyber-attacks on its infrastructure or electronic services.
- Cyber Intelligence – the aim is to share threat intelligence more effectively, and to use it for the early detection and prevention of cyber-attacks.
- Human Factors in cyber security – The aim is to empower the human element in cyber security. The human factor includes offenders, victims of cybercriminals (e.g., banking employees and customers) and actors that play a role in tackling cybercrime (e.g., SOC analysts, software developers).

This last research line was newly introduced in 2018, replacing the research line 'secure transactions'; this was because of changing (shared) research interests and priorities.

Where the beginning of the SRP focussed primarily on producing results, we soon reached a phase in which the first results became available. Results were both short term (that were applied directly by the SRP partners) and long term (which provided input for strategic decisions). For each result we select appropriate follow-up in either publication, applying it in the operational environment of the partners, commercial exploitation or other. We make results public where possible, so also society can benefit from these results and enhance its cyber resilience posture; one clear example being the magazine that now is in front of you. But we also have presented at conferences, produced white papers and we cooperate with Enisa to publish the CTI capability framework that was developed in the program. Another example is the spin-off company from TNO (Sightlabs) that also has taken over some of the tooling that was developed in the program; so the professional support on and further development of this tooling, which is used in security operations by some of the partners, is guaranteed.

> “ Our society becomes more and more digital and cyber security has become an essential element of our everyday life.
> At the same time, technology is changing extremely fast and innovations enter the market every day. Information security teams can only keep up with that rate of change and discover how to protect these new technologies against a very volatile threat landscape, when they adopt a learning culture and exploring attitude. The SRP allows CISO’s and researchers to explore the near future by applying many difference scientific domains. This is essential as to be a successful CISO in these times, one has to be a ‘CISO Universalis’.”

Martijn Dekker
CISO ABN AMRO

Physiological measures to optimize performance of security analysts

Anne-Marie Brouwer (TNO), Richard Kerkdijk (TNO), Ron Luttik (ABN AMRO), Wieke Oldenhof (TNO)

While security monitoring and incident response operations are increasingly automated, it is not likely that human analysts will ever fully disappear from Security Operations Centers (SOCs), fraud management teams or similar environments. The automation of relatively straightforward (standardized) work will, however, gravitate analysts' duties towards the more sophisticated fraud schemes and cyber-attacks. Since this might increase the demand on such things as expertise, focus, creativity and resilience to stress, it is interesting to consider the mental state of fraud and security analysts. At what times and under what circumstances are they stressed or overloaded, when can they focus themselves best? The SRP program investigated the potential of physiological measurement to acquire such insights.

To gain knowledge about the mental state of fraud and security analysts, they might be questioned about their experienced stress, mental effort and focus after finishing work. This approach, however, is known to introduce so called "recall biases". Questioning analysts while performing their work (typically about how they feel at that particular moment), reduces such biases but disrupts the work flow and puts extra load on the analyst. Thus, this project explored the extent to which physiological signals such as skin conductance and pupil size can aid in monitoring the analysts' mental state.

From theory...

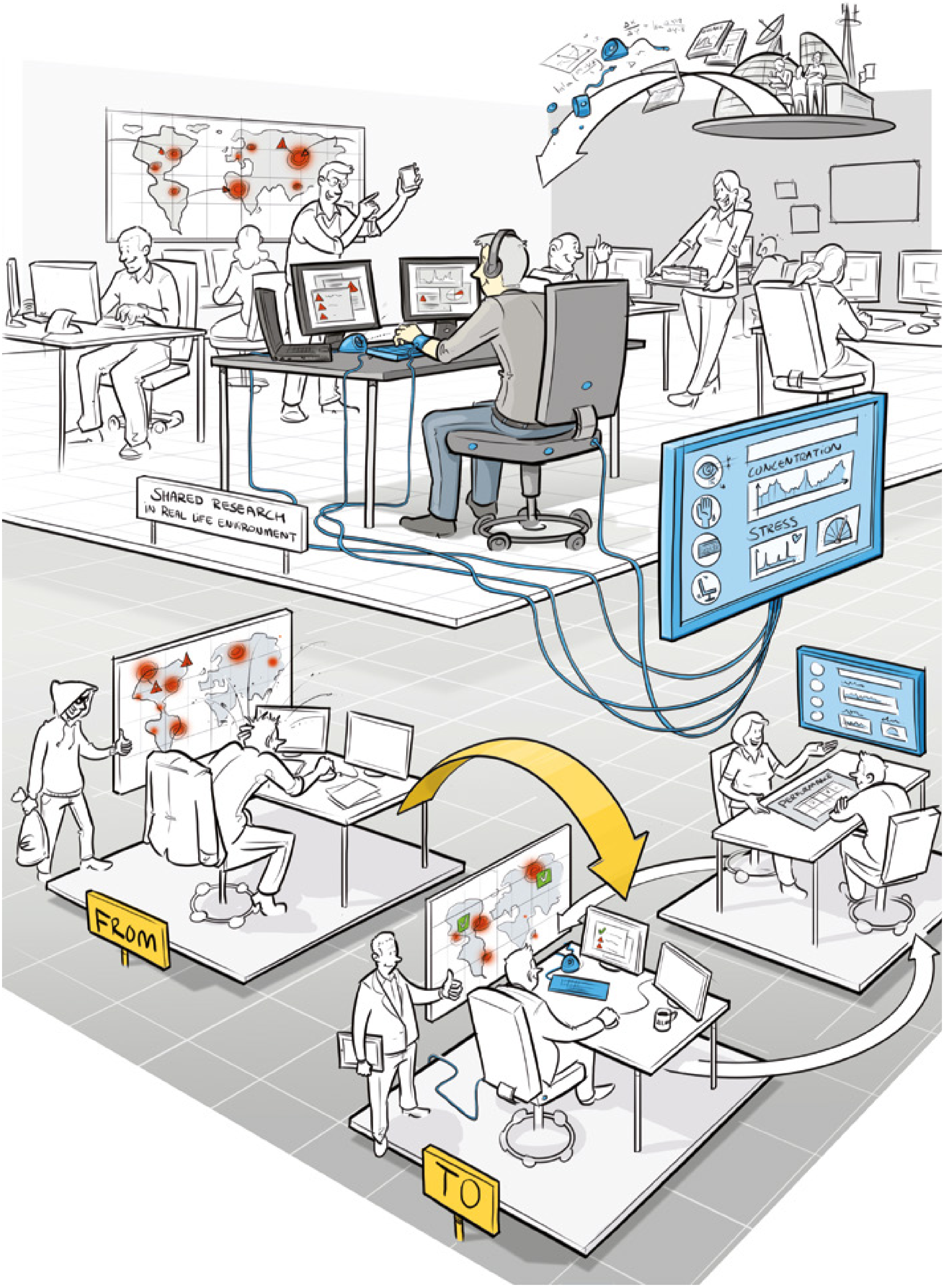
Skin conductance reflects the electric conductivity of the skin which is affected by activity of the sweat glands. Both skin conductance and pupil size are innervated by the sympathetic nervous system that is active when the body prepares for action ("fight or flight") relative to the parasympathetic ("rest and digest") nervous system. Skin conductance and pupil size have indeed been found to reliably associate with mental arousal, e.g. resulting from increased task difficulty or mental effort, social stress or even tasting a disliked drink. This indicates that physiological signals are not very specific and require context information to be interpreted. Compared to questioning, however, these physiological measures have the advantage that they can potentially provide continuous information about the analyst's mental state without disrupting him or her from the task and without possible biases.

While as mentioned above, relations between mental state and physiological signals have been repeatedly demonstrated, such reliable demonstrations mainly stem from laboratory experiments. In such experiments an effort is made to induce certain mental states artificially. Factors that affect physiological signals apart from mental state, such as body movements and light intensity, are strictly controlled. In this project we explored whether skin conductance and pupil size as recorded in a real cyber security working environment could provide meaningful information about the analysts' mental state.

...to experiment....

The project experimented with physiological measurement techniques in ABN AMRO's fraud monitoring center, where around 20 specialists respond to fraud alerts on a 24*7 basis. The setup resembles that of a Security Operations Center

Skin conductance and pupil size have the potential to provide continuous information about the mental state of analysts without disrupting him or her from work.


SHARED RESEARCH
IN REAL LIFE ENVIRONMENT
CONCENTRATION
STRESS
PERFORMANCE
FROM
TO

The results obtained in ABN AMRO's fraud monitoring facility should be equally applicable in similar working environments such as a SOC.

(SOC), albeit that the fraud team not only handles on-screen alerts but also engages with victims of fraud that report (potential) incidents via phone. While ABN AMRO standardized the general process of handling fraud cases, the work of its fraud analysts is typically not prescribed in detailed playbooks or scripts. Rather, much of the actual fraud handling relies on the creativity and analytic skills of analysts on the floor. This characteristic made the environment particularly interesting for mental state measurements.

Eleven fraud analysts were recorded during the experiment, ten of which completed the planned four hours of physiological monitoring. The experiment focused on the effect of multi- versus single tasking. For two hours, each analyst worked only on dealing with alerts from the on-screen queue (single tasking), while in the other slot of two hours this was combined with other tasks such as answering phone calls (multi-tasking). Analysts were outfitted with a new type of wearable skin conductance sensor (EdaMove4), and an eye tracker (Tobii TX300) was located underneath one of their monitors. The eye tracker recorded pupil size as well as eye movements.

In addition to the technical measurements, analysts were questioned about their experience, both through an elaborate questionnaire after recordings had ended and through a pop-up screen that appeared every 10 minutes. The analysts were asked to quickly respond to the pop-up screen and the response time to the pop-up was registered as well.

...to tangible results!

Despite the uncontrolled, real life setting, the quality of the recorded data was satisfactory and the recordings did not noticeably impede the analysists' work. We did not find differences between multi-tasking and single-tasking for any of the measures, except that reported mental effort was somewhat higher for multi-tasking than single tasking. However, when the data was examined from the preferred type of working of the individual analyst, a consistent pattern emerged. Four analysts preferred multi-tasking, four preferred single tasking and two had no preference. Reported focus tended to be highest during the preferred type of working, be it single or multi-tasking. Reported stress and mental effort were relatively high for multi-tasking compared to single tasking for analysts who disliked multi-tasking. Consistent with this, these analysts showed a relatively high pupil size and skin conductance during multi-tasking. Analysts who dislike, and as evidenced by our results, become relatively stressed by multi-tasking, responded relatively quickly to the pop-up. This suggests that multi-tasking is stressful to them because of their effort to quickly pick up each sub-task rather than prioritize.

Perspective and future work

The consistent patterns observed in the experiments reveal that physiology can indeed provide insight into the mental state of fraud and security analysts. Here we note that the results obtained in ABN AMRO's fraud monitoring facility should be equally applicable in similar working environments such as a SOC. Collecting physiological data in such 24*7 operations centers may be valuable because analysts themselves might not always be aware that they are experiencing stress or concentration relapse (or simply be reluctant to express this). Physiological signals might prompt an operations manager to inquire about the well-being of specific team members and for instance make adjustments in the duty roster to avoid overload and errors in the appraisal of fraud and security alerts.

To further substantiate the project's findings, it would be useful to extend the experiment to other (but similar) operations facilities and record more cyber security operators or analysts over a longer period of time. It would also be interesting to include some alternate physiological characteristics in the measurement scheme (e.g. body movement and posture which can be measured through pressure sensors embedded in office chairs) and to establish a more explicit link between the measurements, the specific tasks that an analyst was conducting and the extent to which these tasks were in fact performed appropriately.

Bibliography

Brouwer, A.-M., Hogervorst, M. A., Oudejans, B., Ries, A. J. and Touryan, J. (2017). EEG and Eye Tracking Signatures of Target Encoding during Structured Visual Search. Frontiers in Human Neuroscience 11:264.

Brouwer, A.-M., Zander, T. O., van Erp, J. B. F., Korteling, J. E. and Bronkhorst, A. W. (2015). Using neurophysiological signals that reflect cognitive or affective state: six recommendations to avoid common pitfalls. Frontiers in Neuroscience 9:136.

Dawson, M.E., Schell, A.M., Filion, D.L. (2007). The electrodermal system. In: Cacioppo, J.T., Tassinary, L.G., Berntson, G.G. (eds.) Handbook of Psychophysiology. Cambridge University Press, Cambridge

Hogervorst, M. A., Brouwer, A.-M., & van Erp, J.B.F. (2014). Combining and comparing EEG, peripheral physiology and eye-related measures for the assessment of mental workload. Frontiers in Neuroscience 8:322.

Kapoor, A., & Picard, R. W. (2005). Multimodal affect recognition in learning environments. In Proceedings of the 13th annual acm international conference on multimedia.

Moskowitz, D.S., Young, S.N. (2006). Ecological momentary assessment: what it is and why it is a method of the future in clinical psychopharmacology. J. Psychiatry Neurosci. 31(1), 13–20

Vanhala, T., Surakka, V., Anttonen, J. (2008). Measuring bodily responses to virtual faces with a pressure sensitive chair. ACM International Conference Proceeding Series, 358: 555-558 NordiCHI 2008: Building Bridges - 5th Nordic Conference on Human-Computer Interaction.

Widmann, A., Schröger, E., Wetzel, N. (2018). Emotion lies in the eye of the listener: Emotional arousal to novel sounds is reflected in the sympathetic contribution to the pupil dilation response and the P3. Biological Psychology, 133, 10-17

“ With the banking sector moving into the digital era rapidly, customer needs are more and more innovatively addressed via multi-channel offerings. Put together with the open banking regulations, this puts a challenge on the cyber security organisations within the financial industry.

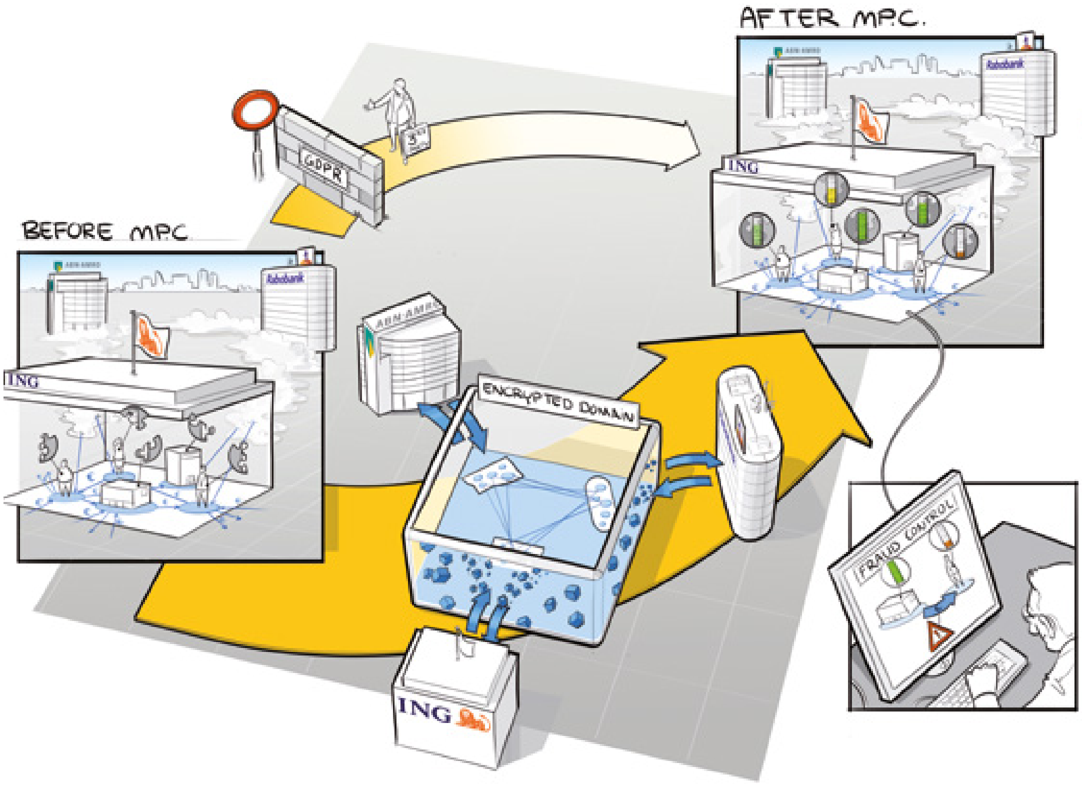
Banking is all about trust, so we continuously need to invest in our defence structure. Besides the technologic developments, this means also developing our human firewall. Because it is crucial to combine both in preventing data breaches. I strongly support the SRP initiative were the banks join forces to tackle the challenges put upon us.”

Mimoent Haddouti
Global Head First Line Risk & Security Rabobank

How Google's PageRank inspired us to improve collaboration in fraud detection.[1]

Collaborative fraud detection using secure multiparty computation

Alex Sangers (TNO), Mark Wiggerman (ABN AMRO), Daniël Worm (TNO)



The risks of sharing data for companies as well as public services are loss of trust in services, integrity, financial losses, societal damage, and damaged reputation.

Introduction

Cyber security, anti-fraud and other anti-crime activities highly benefit from collaboration between involved parties like financial institutions, governments and law enforcement agencies. Public and private sectors are stimulated by regulators to perform joint activities and share data, e.g. threat intelligence, as there is a common goal to combat this type of crime. Relevant data to share includes lists of known criminals, confirmed money mules and known malicious IP addresses. Sharing operational data on customers, transactions and events between different organizations would be advantageous as well, but this has always been strictly restricted due to competition and privacy regulations, especially if it concerns personal data of customers and employees. The risks of sharing data for companies as well as public services are loss of trust in services, integrity, financial losses, societal damage, and damaged reputation.

The financial sector is continuously fighting the misuse of the financial infrastructure for criminal activities like fraud and money laundering. Financial crime detection is a typical example of a

[1] This article is partly based on the more detailed scientific paper [2].

Financial institutions do not need the data itself but only the result of the analytics performed on that data.

setting where multiple parties share a common interest, but confidentiality and privacy regulations prevent collaboration [1]. In a payment transaction a financial institution typically only knows details if it was involved in the payment. Financial institutions could be much more effective at combatting financial crime if they would be able to access results from analytics based on each other's data, as well as data from other related organizations. However, since such data is often too sensitive to share, there is no straightforward way of accomplishing this.
A possible solution would be to have a single trusted third party that all financial parties are willing to confide their financial secrets to. However, it may be difficult or impossible to find such a party. In addition, it may be very expensive. An important observation is that financial institutions do not need the data itself but only the result of the analytics performed on that data. Therefore we developed an alternative solution, without needing a trusted third party, but still achieving the same security goals. The cryptographic technology that overcomes the described dilemma is Secure Multi-Party Computation (MPC).

Secure Multi-Party Computation (MPC)

MPC protocols are cryptographic techniques that allow multiple parties to collaboratively evaluate a function on private input data in such a way that only the output of the function is revealed, i.e. private input remains private. MPC could be explained as the implementation of a trusted third party that collects all relevant input data, evaluates the desired function and only reveals its output. Already in the 1980s it was shown that any computable function can be evaluated securely, i.e. in an MPC fashion. However, early MPC protocols came at a cost as they introduced significant computation and/or communication overhead, deeming this protocols impractical in many situations. Over the years progress has been made and research interests have shifted towards practical applicability making MPC ready for deployment.

PageRank for fraud detection

In the SRP, we selected a use case in the area of fraud detection in order to evaluate the possible application of an MPC approach. We focused on financial transaction networks. In mathematical terms a network is called a graph. A financial transaction consists of a source bank account, a destination bank account, an amount and a timestamp. A set of transactions can be modelled as a graph where nodes (circles) represent bank accounts and links (arrows) represent the transactions between accounts.
It was shown that graph-based features can be used to reduce the false-positives of existing fraud detection techniques [3]. One of these graph-based features is PageRank, originally developed by Google to rank websites in their search engine results. PageRank estimates the popularity of a website, by considering how central a website is in the graph of all websites: the more central, the higher the PageRank value. PageRank can also be computed for transaction networks: For every account number (node) in the network (graph) one can calculate a value which is the PageRank of that account number. Although it is no silver bullet, it has been shown that transactions to accounts with high PageRank are less likely to receive fraudulent transactions. Because of this property, we have chosen to develop an MPC solution for PageRank.

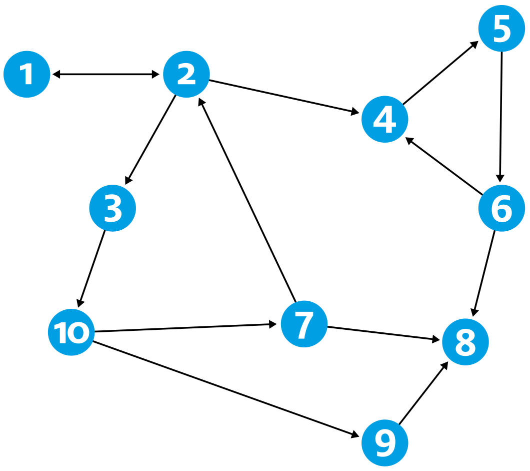


Figure 1: Example of a small transaction graph. Nodes represent bank accounts and links represent transactions.

The idea for detecting fraudulent transactions is to build a transaction graph based on historical transaction data. Based on this graph, the

PageRank value for each bank account is computed. As soon as a new transaction request comes in, this transaction request has to be assessed within milliseconds on whether it is fraudulent. This assessment can be based on various existing detectors, for example using geolocation. The graph-based features such as PageRank from the historical transaction graph can be used to improve this assessment. If the transaction request is assessed to be (likely) fraudulent, it can be declined or delayed for further investigation.

PageRank computation

Inspired by the original idea of Google, the PageRank model for transactions can be seen as money following transactions with some probability p, and jumping randomly to any bank account with probability 1-p. Each time the money ends up in a dead-end bank account, it will randomly jump to any bank account. If the money follows this behaviour infinitely long, then the PageRank value of the bank accounts is the proportion of time spent by the money in the bank accounts. The lower the PageRank value of a bank account, the more likely that such a bank account is fraudulent if it receives large sums of money.

PageRank

Mathematically, the PageRank is the stationary distribution of a Markov chain. An efficient algorithm to compute the PageRank is given by the power method. The PageRank value of node j at the k^{th} iteration of the power method is denoted as x_k^j and the power method is given by the following iterative scheme.

$$X_{k+1}^{j} = \frac{1-p}{n} + p \sum_{i \epsilon s\,(j)} \frac{x_k^i}{c_i}$$

where p is a fixed probability, n the total number of nodes, c_i the outdegree (number of outgoing links) of node i, and $S(j)$ is the set of nodes linking to j. This formula is linear and consists mostly of additions, which is a nice property for some MPC solutions. Under mild conditions, it can be shown that the power method has a convergence rate of p. For p=0.85 the power method converges within 50 till 100 iterations independent of the graph size.

Cooperation is required to analyse the combined transaction graph

The PageRank algorithm can be deployed at each individual financial institution to detect fraudulent transactions. However, each financial institution oversees only a part of the global transaction graph. To be precise, a bank only sees the transactions if the source and/or destination bank account is managed by that bank. Figure 2 shows an example of how the transaction graph consists of parts that are visible to each financial institution. The transaction graph can be constructed by combining the transaction data that is available to each individual financial institution.

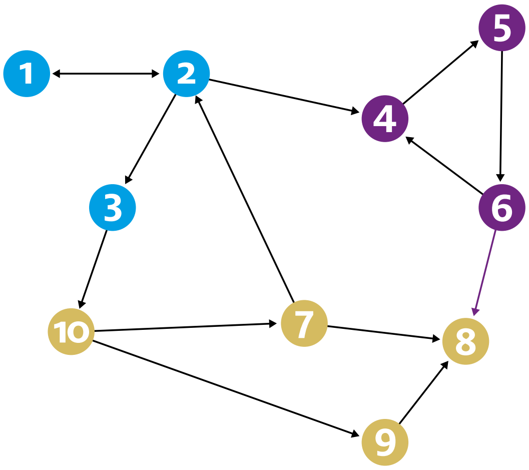


Figure 2: Small example of how three subgraphs (indicated by three colors) can be coupled to the combined transaction graph.

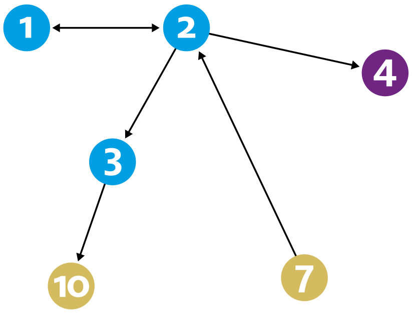


Figure 3: The part of the transaction graph that is visible to the blue financial institution.

The idea for detecting fraudulent transactions is to build a transaction graph based on historical transaction data.

During the project we have shown that the PageRank values more accurately represent the true PageRank values (of the whole financial transaction network) if financial institutions would collaboratively compute the PageRank values compared to them doing this separately. This effect is even stronger for financial institutions with a relative small number of bank accounts. Furthermore, the PageRank values of bank accounts with many interbank transactions are significantly more accurate if the PageRank is computed collaboratively.

However, the transaction data is sensitive data and cannot be shared between financial institutions for this purpose. Given Figure 3, assume that the blue bank wants to compute the PageRank values of its nodes. In order to compute the PageRank values of the blue nodes, the blue bank requires information of the nodes that have a link directed to the blue nodes. For example, node 7 contributes to the PageRank of node 2, so the blue party should know the number of outgoing links of node 7 and the intermediate PageRank value of node 7. However, these values are known by the yellow bank but it is a secret to the blue bank. Additionally, the intermediate PageRank values also leak information about transactions.

We designed a secure PageRank solution that is able to collaboratively compute PageRank of coupled transaction graphs without leaking information about individual transactions.

We designed a secure PageRank solution that is able to collaboratively compute PageRank of coupled transaction graphs without leaking information about individual transactions.

Secure PageRank algorithm

Developing an MPC solution for PageRank is non-trivial for several reasons. MPC may introduce a significant overhead. Furthermore, most cryptographic protocols work over finite groups[3], rings or fields and not over real numbers. These challenges can be tackled by developing a specific and efficient MPC protocol. We developed an MPC protocol using additive homomorphic encryption.

In depth: the secure PageRank solution

Some encryption schemes have the property that computations can be performed with ciphertexts. Such schemes can form important building blocks for MPC solutions. This property is called fully homomorphic encryption (HE) if both additions and multiplications can be performed with ciphertexts. However, fully HE performs poorly in practical applications as a general solution. Additively HE is much faster but only allows for additions in the encrypted domain. Additively HE has the following properties:

- Two ciphertexts can be multiplied, with the same result as if adding the decrypted ciphertexts;
- A ciphertext can be exponentiated with a known/plaintext integer, with same result as if multiplying the decrypted ciphertext with the known integer.

Recall the PageRank formula:

$$x^{j}_{k+1} = \frac{1-p}{n} + p \sum_{i \epsilon s\,(j)} \frac{x^{i}_{k}}{c_i}$$

The PageRank algorithm has to be adjusted to efficiently use additive HE. Firstly, the formula should be adapted to work with integers instead of real numbers. This is solved by multiplying the formula with a large value f_x. All values are then rounded. Secondly, the division by c_i in every iteration is too expensive in practice, requiring an approximate integer division. This is solved by multiplying x_k^i each iteration with a large value f_c. This way, the division by c_i can be replaced by a multiplication with f_c/c_i. Thirdly and lastly, the outdegree c_i of node i is a privately known number and cannot be shared between parties. A crucial observation is that all nodes are managed by one of the parties participating in the protocol. Therefore, the number c_i is known to the party that manages node i and this party can execute the multiplication by f_c/c_i. For more details we refer to the scientific conference paper [2].

[3] Groups, rings and fields are mathematical objects often used in cryptography.

Our developed solution achieves computational security in the semi-honest model, i.e. under the assumption that all parties follow the prescribed protocol no party will be able to learn any more information other than the output of the algorithm and any information that follows from that. In our setting, each party will learn the final PageRank values of its own nodes (bank accounts). The solution is implemented using the Paillier Homomorphic Encryption library in Python [4]. The key generation involves a public key, and a partial private key for each party. The private keys ensure that ciphertexts can only be decrypted collaboratively. Generating the keys is a onetime effort and is implemented using a trusted third party. Currently, a distributed key generation algorithm is in development in the Shared Research Program, removing the need for a trusted third party all-together. The number of communication rounds, excluding the key generation, equals the number of PageRank iterations plus 1.

Results

For practical application, it is important to show the accuracy and scalability of the secure PageRank algorithm. The results are based on sampled, anonymized transaction data. Bank accounts, amounts and times are hashed or randomized but in such a way that bank accounts can be coupled in different transactions. Four different datasets are sampled from the transaction data with 100, 1.000, 10.000 and 100.000 bank accounts and the transactions between themselves. The sampled transaction data is divided among three artificial parties, each of whom only see a transaction if the source and/or destination bank account is managed by that artificial party.

Firstly, the accuracy of the secure PageRank algorithm is measured by comparing the results to the outcome of normal PageRank. A maximum relative error below 0.05 is acceptable. As can be seen in Figure 4, the effect of rounding errors in the secure PageRank algorithm is small. Secondly, the computation time increases linearly with the number of nodes in the transaction graph, as shown in Figure 5. This is consistent with the theoretical scalability.

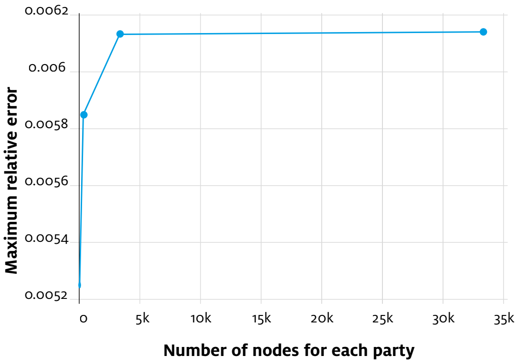


Figure 4: The maximum relative error for increasing sample size of the transaction graph.

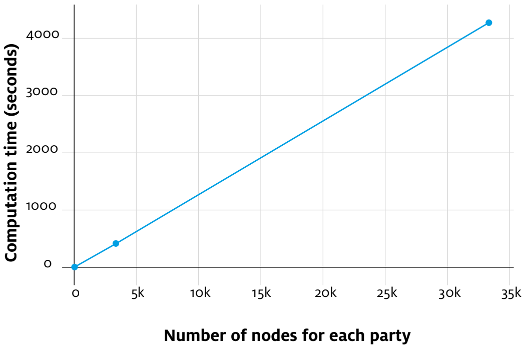


Figure 5: The computation time for increasing sample size of the transaction graph.

The secure PageRank algorithm is also highly parallellizable (for each party). Extrapolation of these results indicate that, for a secure 3-party PageRank computation with 30 million nodes and average outdegree of 80, the current Python implementation would require less than 11 days to compute the PageRank values. When implemented in C++, this can be further improved to within 1 day.

Conclusion

Financial institutions can highly benefit from collaborative fraud detection. Relevant data exchange, however, is limited due to privacy and legal restrictions. Collaborating organizations actually do not need the data itself, only the result of the analysis, the computation. Some techniques such as PageRank detect fraudulent transactions using historical transaction data in order to find anomalous patterns that deviate

The application of the MPC solution is not limited to fraud detection but can e.g. also be applied in Security monitoring & detection.

Each financial institute learns the PageRank values of its own bank accounts using a collaborative decryption scheme.

from normal transaction patterns. Individually, financial institutions only see a part of the global transactions and would benefit from a more complete view on all the transactions. In the Shared Research Program a secure PageRank algorithm has been developed to compute the PageRank of the combined transaction graph of collaborating financial institutions, without sharing any data on transactions. Each financial institute learns the PageRank values of its own bank accounts using a collaborative decryption scheme. The algorithm has been implemented in Python and experiments show that securely analyzing features of a large-scale network that is distributed over multiple parties is feasible. The application of the MPC solution is not limited to fraud detection. Current research focuses on generalizing and extending the solution for secure collaborative money laundering detection. And on how to enable secure following of cash flows and propagate risk metrics across transaction networks. The possibilities with MPC are countless. Think of opportunities such as securely sharing Indicators of Compromise between organizations or collaboratively detecting botnets. Do you have a suggestion on a possible MPC application? We are always interested in exploring new ideas!

Bibliography

[1] Poortwachter bank ziet veel, maar mag weinig – Financieel Dagblad 27 november 2018

[2] Sangers, A., Heesch, M. van, Attema, T., Veugen, T., Worm D., Wiggerman M., Veldsink J., Bloemen O.: Secure multiparty PageRank algorithm for collaborative fraud detection. In: Financial Cryptography and Data Security, February 2019. See https://fc19.ifca.ai/preproceedings/61-preproceedings.pdf

[3] Molloy, I., Chari, S., Finkler, U., Wiggerman, M., Jonker, C., Habeck, T., Park, Y., Jordens, F., van Schaik, R.: Graph analytics for real-time scoring of cross-channel transactional fraud. In: Financial Cryptography and Data Security, February 2016.

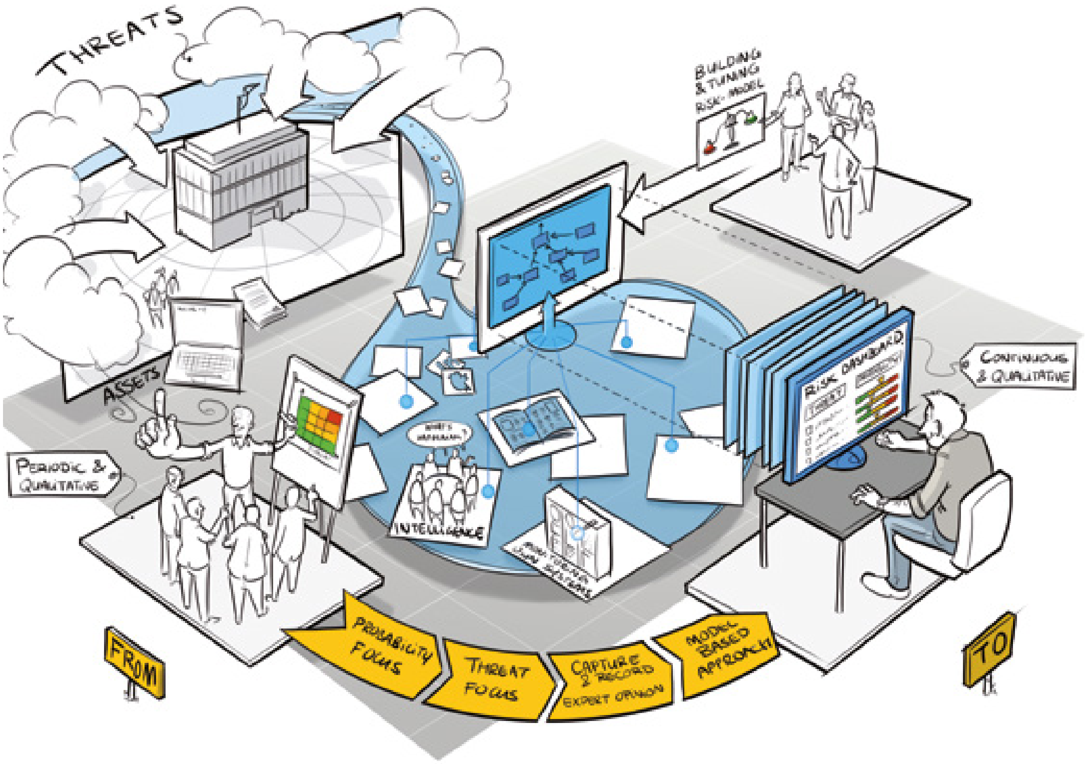
[4] A Python 3 library for Partially Homomorphic Encryption using the Paillier crypto system, https://python-paillier.readthedocs.io/en/develop/ - 2 June 2016.

“ Everyone has a plan until they get punched in the mouth (Mike Tyson). This is true for both life and for cybersecurity. We need to be better prepared for the unexpected. Not only on paper by writing procedures, policies and cool reports. But by doing, exercising, researching, discussing & sharing experiences with our sparring partners. The Shared Research Program gives us exactly that opportunity. To get in the ring and start researching & learning, together with creative and talented people from other companies & sectors. I am convinced that we all benefit from this cooperative approach. Expect to get hit. Enjoy it. And improve.”

Leon Kers
CISO Volksbank

Quantifying Cyber security Risks

Reinder Wolthuis (TNO), Frank Phillipson (TNO), Peter Rochat (Volksbank), Bert van Ingen (Rabobank), Sander Zeijlemaker (ING), Daniël Gorter (Achmea)



For financial service providers (but also for companies in many other sectors), it is important to understand their risks. Many business decisions are based on estimations of risk and in the financial sector, risk management is one of the key processes in the day-to-day business. Until recently this risk management was mainly focused on financial risks. But currently, financial services rely heavily on electronic channels and complex IT infrastructures, which introduces the risk on cyber-attacks. These attacks might lead to considerable impact on reputation, loss of confidential information or loss of money. This triggered the need for more attention for (cyber) security risk management, a process that is now implemented at all financial providers.

Traditionally, security risk management is a qualitative process based on expert opinion and information at hand; periodically a group of experts gathers, reviews whether the existing risks are still applicable, verifies whether existing risks have correct risk levels, and whether new risks should be added to the list. This usually results in a rather good insight in risks, although not very timely (depending on the periodicity of the meetings), usually formulated qualitatively (e.g. in terms of low, medium, high), depending heavily on expertise of staff that is present during the risk assessment sessions and without a traceable reasoning process. Also, current cyber security risk management approaches usually have an ‘asset based’ approach, meaning that the risks are established for an asset, such as a process,

In the financial sector, risk management is one of the key processes in the day-to-day business.

a server or a website. As a result, risks cannot be sufficiently related to impact on business processes. These characteristics of cyber security risk management hinder the effective use of cyber security risks in decision making processes.

In the Shared Research Program (SRP) Cyber Security we have developed a quantitative and actual risk assessment methodology, that uses available actual information to quantify risks. The methodology focusses on potential cyber-attacks and their resulting business impact. This leads to a near real-time traceable quantitative risk process, because available information is processed and the risks are automatically updated. The methodology was evaluated against some real-life use cases and in the risk departments of banks. In this article we share these experiences.

Risk assessment

Risk is a metric to estimate the impact of a threat and the likelihood that a threat really leads to this impact. Risk can in its most simple form be expressed as the product of two parameters:

- The likelihood that a threat materializes;
- The impact of a threat when it materializes.

Risk = Likelihood (threat) * Impact (threat)

An example of a threat is a Distributed Denial of Service (DDoS) attack. During a DDoS attack, many computers are used to send large amounts of Internet traffic to one specific target website, with the aim to disturb the accessibility of the website or to even bring it down completely. The potential impact would be that the website owner cannot deliver its services any more through the website and suffers reputational damage and/or financial loss. The likelihood that the threat actually occurs depends on many things, such as the attractiveness of the organization for attackers, the means that an attacker has to generate such an attack, the potential gain that an attacker can make (e.g. by extortion) and the measures that the organization under attack has implemented to mitigate DDoS attacks.

Risk is a metric to estimate the impact of a threat and the likelihood that a threat really leads to this impact.

Risk Quantification

Risks can be expressed in qualitative values or quantitative values. Qualitative risk assessments usually define risks in scales that are expressed in discrete levels such as Low, Medium, High or 1 to 5. Each level in such a scale needs to have a definition that suits the context of the risk assessment, to be able to qualify a risk. This is done both for the impact and for the likelihood of the risk and combined this leads to the actual risk level.

The results of qualitative risk assessments provide a good insight in risks, but there are some drawbacks:

- They depend heavily on the definition of the discrete levels and to really understand risk levels, this definition should also be provided;
- There usually is little distinctive power; i.e. on a scale of ‘low, medium, high’, most risks will score ‘medium’, which is not a good base to decide which risks need to be mitigated.

Quantitative risks do not have these disadvantages; they do not need definition tables and usually have more distinctive power because of the theoretically endless number of values it can have.

Estimations for the *impact* of cyber-attacks (e.g. “how much financial loss is caused by a DDOS attack”) can be expected to be more-or-less time invariant, provided the IT infrastructure and the various business processes remain the same. However, some impact aspects could very well change over time (such as reputation loss or fines). Usually the impact is quantified by making it financial taking into account costs for response & repair, costs of loss of production time, costs of repairing reputational damage, costs of injuries, cost of fines etcetera.

The *likelihood* of a risk is usually quantified with support of model-based approaches such as Fault/Event Tree Analysis, Attack Graphs/Trees, (Monte Carlo) simulation, Markov Models or Bayesian (Belief) Networks. These models are used to derive the likelihood of a threat, given valid data. Where data is not available, eliciting expert opinion methods can be used. Most methods help to reason in cases of uncertainty and interdependencies (correlated events), which are both hard to perform by humans.

Next to these model-based approaches, current developments in AI, such as Deep Learning, also offer possibilities in threat identification and risk quantification. Here, data is analyzed and models are trained to recognize anomalies in static and dynamic situations. However, here the explainability or traceability lacks.

Building a usable quantified Risk Assessment methodology

The methodology that we have developed is based on the following design parameters and design decisions.

1. We have chosen to develop a methodology that quantifies the likelihood part of a risk. The likelihood part is usually not time-invariant, it could change fast and frequent and we expect that we can use available information to track this change in an automated way;
2. We have chosen to take a threat based approach (contrary to e.g. an asset based approach). This means that we build the model based on a threat that could lead to a certain (defined) business impact (e.g. DDoS attack, identity theft);
3. We have chosen to take a model based approach. We model the processes, infrastructure, the attacker and other assets that are related to the threat. We also include the mitigating measures in the model, that will influence the likelihood of the threat actually leading to business impact;
4. We have chosen for a model that is able to structurally capture and record expert opinion in a transparent way. In this way, we can always trace back why the model was built in a certain way and revise the model when changes (internally or externally) occur.

Based on the points above, we have decided to use a Bayesian Belief Network (BBN), which enables reasoning with uncertainty. It translates uncertainties in threats, effectiveness and availability of protective measures into probability that a certain target is affected.

The developed methodology uses a model and threat based approach and quantifies the likelihood part of risk.

Bayesian Belief Networks

A Bayesian Belief Network (BBN) is a probabilistic graphical model that represents a set of random variables and their conditional dependencies. In the context of the risk methodology, for example, the random variables of interest will be: threats, measures, impact, etc. One of the advantages of a Bayesian network is that these relations do not have to be deterministic. The uncertainty in different threats and in the effect of measures can be modelled. The sensitivity of critical decisions can be evaluated and different scenarios can be analyzed.

In a BBN several types of nodes can be distinguished (see Figure 1). Each node may have multiple states.

- Input (or: Root): nodes with only outgoing arrows. An input node needs as input a definition of states it can be in and the probability of occurrence of each of these states. An input node can be fed by an automated or a manual stream of information that influences its state and by that, through the Intermediate nodes it is connected, influencing the state of Result nodes;
- Intermediate: nodes that are located on the inside of the network and that have one or more incoming arrows from 'parent' nodes and one or more outgoing arrows to other Intermediate nodes or to End nodes; These nodes need as input a definition of states it can be in and the probability that it will be in each of the states, given the state of the parents, in the form of a probability table.
- Result: nodes with only incoming arrows, which represent the final result. These nodes need as input a definition of states it can be in and the probability that it will be in each of the states, given the state of the parents.

The way that information or incoming arrows influences the states of a node needs to be defined in the probability tables. Elicitation of the probability tables can be done by using evidence or expert opinion, who has to quantify its belief. A method for this can be found in [Cooke] and [Wisse].

The foundation of the methodology is a Bayesian Belief Network (BBN), which translates uncertainties in threats, effectiveness and availability of protective measures into probability that a certain target is affected.

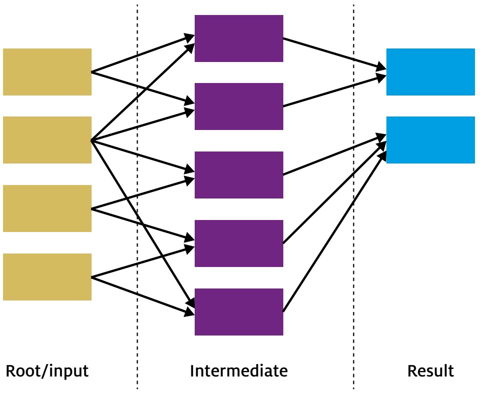


Figure 1: Types of nodes in a Bayesian Belief Network.

The Quantified Risk Methodology

Below the methodology for Quantified Risk management is described, inspired by the 'Business continuity response-recovery chain' in [Phillipson] and the threat and model based approach of [Phillipson2]. In each step, we apply the methodology on a threat example, in this case a DDoS attack (as was done in the Proof of Concept).

Step 1. Identify the threat and the business impact to be modelled

In this step, the threat needs to be described as detailed as possible. Also the business impact needs to be defined: what does it encompass (regulatory fines, service disruption, etc.) and which levels can be distinguished (business impact still is defined as qualitative discrete levels).

The example is built around a DDoS threat. There are many types of DDoS threats (network level, application level, flooding etc.). We have narrowed the example down to a 'Network level DDoS attack'. Please note that we need to build a model for each type of DDoS attack that is applicable in this context. In this case, the business impact is on consumer bank transfers (retail banking) and we have defined three levels of business impact:

- No impact – non-measurable impact;
- Medior impact – 50-100K euro costs, disruption 1-4 hours, medium reputation damage;
- Major impact – over 100K euro costs, disruption > 4 hours, major reputation damage.

Step 2. Identify the business processes and assets that are involved in the attack.

In this step, all the business processes that will be impacted by the defined threat need to be listed, including the major assets. We need to go into a certain detail, but not too much detail, because then the model will become too complex.

In the example of a 'Network level DDoS attack' we have identified the following business processes and assets: Payment service, SEPA transaction service, Other necessary services (needed for the payment process to function), Operating system, Application, Network.

Step3. Identify the mitigating security measures that are in place

In this step, all security measures that are in place that can reduce the probability that the threat leads to impact need to be listed. Also here, it is necessary to go into a certain level of detail, but not too much detail.

In the example of a 'Network level DDoS attack', some examples of potential mitigating measures are: Mitigating business measures, Incident response (on three levels), Testing and training (of incident response teams and processes), External DDoS mitigation (by an external service provider), Attack traceback (the ability to gather information on the source of attack etc.) and Forensics and prosecution. For the full set, see the model in the picture of the model (Figure 2).

Step 4. Identify the actor, its motivation and the means that are available

In this step, the threat actor is defined in a BBN node. It can also be useful to define the actor motivation, the means that an actor has available to launch the attack and the country of origin of the actor.

In the example of a 'Network level DDoS attack' we have identified the following nodes:

- Actor (script kiddy, activist, state sponsored and criminal);
- Actor motivation (extortion, competitor, environmental and/or reputational, thrill seeker, national conflict);
- Country of origin of the actor/attacker (EU, Eastern Europe, Middle East, USA, other);
- Available botnet capacity (the DDoS capacity through botnets available for the actor).

Step 5. Build the model in a BBN

In this step, the nodes are modelled in the BBN, and their interrelationships are determined (by means of connecting arrows).

Step 6. Define the probability tables with relevant experts

In this step, the probability tables are defined. To do this, experts and information are needed to define the dependencies between threats and mitigating measures. Also experts and information are needed to understand the actors and their motivation. It is crucial, for traceability, to record the motivation for the values in the decision table. This can be done in a 'decision table document'.

In the example of a 'Network level DDoS attack' we have made a decision table for the node 'DDoS duration' (see Table 1, that shows part of a decision table), with incoming nodes 'available botnet capacity' and 'actor':

The motivation for this table is that the probability that a long during attack occurs will increase with increasing botnet capacity and with increasing experience of the actor. We define a probability of 0% that there will be a duration of more than 4 hours (H4_PLUS) if the botnet capacity is low.

We now have established the following model of a 'Network level DDoS attack' (see Figure 2)

Actor	Script kiddy				Activist				State sponsored			
Available botnet capacity	Hi	Av	Lo	None	Hi	Av	Lo	None	Hi	Av	Lo	None
H4_plus	0	0	0	0	0	0	0	0	0,3	0,2	0	0
H4	0,3	0,2	0,1	0	0,3	0,2	0,1	0	0,3	0,2	0,2	0
H1	0,7	0,8	0,9	1	0,7	0,8	0,9	1	0,4	0,6	0,8	1

Table 1 – Partial decision table for the node DDoS duration in the model for network level DDoS attack

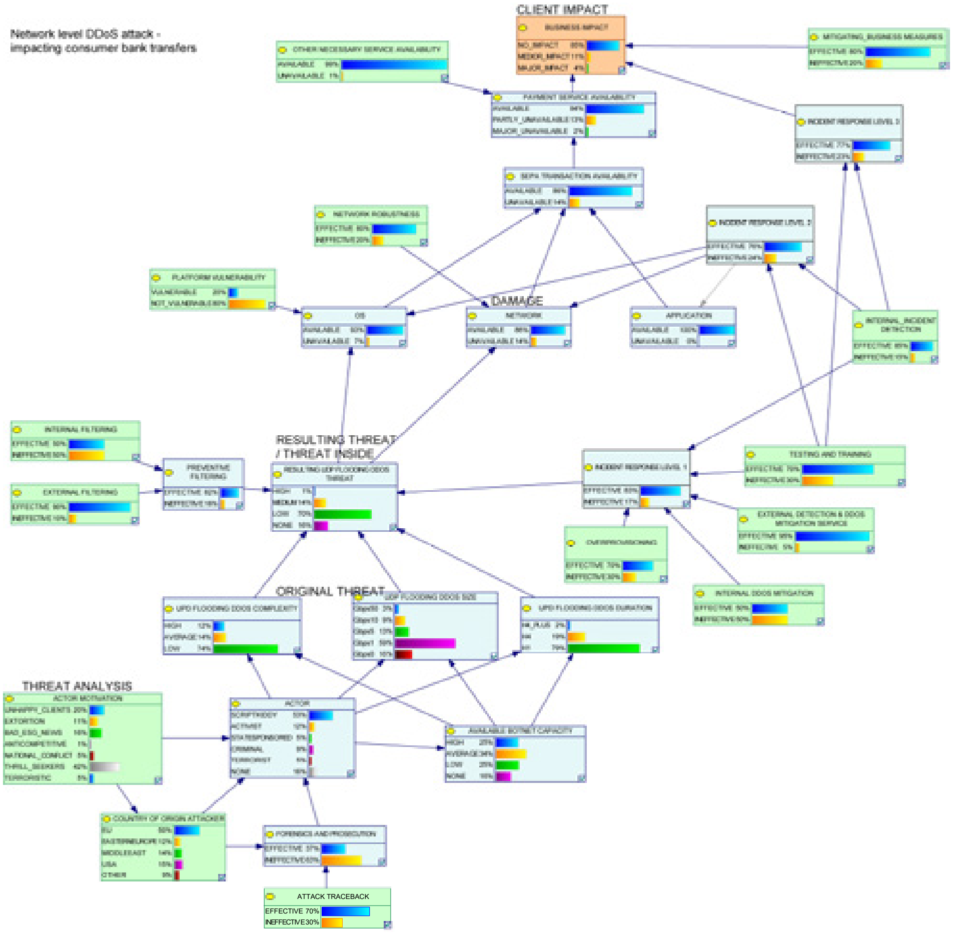

Network level DDoS attack - impacting consumer bank transfers
CLIENT IMPACT
BUSINESS IMPACT
OTHER NECESSARY SERVICE AVAILABILITY
MITIGATING_BUSINESS MEASURES
PAYMENT SERVICE AVAILABILITY
INCIDENT RESPONSE LEVEL 3
SEPA TRANSACTION AVAILABILITY
NETWORK ROBUSTNESS
INCIDENT RESPONSE LEVEL 2
PLATFORM VULNERABILITY
DAMAGE
OS
NETWORK
APPLICATION
INTERNAL_INCIDENT DETECTION
INTERNAL FILTERING
EXTERNAL FILTERING
PREVENTIVE FILTERING
RESULTING THREAT / THREAT INSIDE
RESULTING UDP FLOODING DDOS THREAT
INCIDENT RESPONSE LEVEL 1
TESTING AND TRAINING
EXTERNAL DETECTION & DDOS MITIGATION SERVICE
OVERPROVISIONING
INTERNAL DDOS MITIGATION
ORIGINAL THREAT
UPD FLOODING DDOS COMPLEXITY
UDP FLOODING DDOS SIZE
UPD FLOODING DDOS DURATION
THREAT ANALYSIS
ACTOR MOTIVATION
ACTOR
AVAILABLE BOTNET CAPACITY
COUNTRY OF ORIGIN ATTACKER
FORENSICS AND PROSECUTION
ATTACK TRACEBACK

Figure 2: Model of a Network level DDoS attack.

Experts and information are needed to define the dependencies between threats and mitigating measures.

Step 7. Establish the information that is available to feed into the model

In this step we assess what information can be used to feed into the input nodes (the green nodes in Figure 2) and that will influence the probability table of the input node. This information can be acquired internally (e.g. output from technical systems such as log files or service level reports from suppliers) or externally (cyber threat intelligence sources, reports from national certs, etc.). A translation table needs to be defined, that translates the value of the information sources into probability percentages of the input node. The higher the refreshment rate of the information, the more actual the probability table of the input parameter.

If no (structural) information sources can be found, the probability for an input node needs to be determined by experts in which case it is important to record the considerations of the experts.

Step 8. Develop automated scripts to feed the information in the model

Manually updating the information in the model can be tedious, in particular when it contains a lot of input nodes and/or many information sources. To increase the usability of the model, automated scripts can be developed that overtake this task.

Step 9. Put it into operation

After the model is finalized, the information sources and translation tables are established and optional automation has been implemented and tested, the model can actually be used. It is recommended to, e.g., perform a yearly verification step on the probability tables with experts.

The output of the model can be used in the Risk Management process. But the model can also be used for many different analysis purposes e.g.:

- Scenario analysis: a particular situation is simulated by determining a set of multiple input variables and propagation. What answer does that give in the outcome variable(s)?
- Sensitivity analysis: what effect does varying one input variable have on the outcome variable(s)? E.g. what if the effectiveness of our external mitigation provider decreases?
- Root cause analysis (in case that an attack actually occurred): what has caused the observed state of the outcome or intermediate variable(s)?

The model can also be used for analysis purposes, such as root cause analysis and sensitivity analysis.

Lessons learned and outlook

We have gained many useful insights in building the methodology and conducting a Proof of Concept with it:

- Although it takes considerable effort to implement a model for one threat, the effort seems to be well spent because it provides useful new insights. The model and decision tables will most probably not change heavily over time, so the result of the effort can be used for a longer period. Also, this method ensures that expert opinion is structurally recorded and traceable, making it less depending on (presence of) specific experts;
- The actuality of the output of the model (probability of impact when a threat materializes) depends heavily on the actuality of information sources. But even if the information does not change frequently and the model therefore remains relatively static, the model is useful because of the quantified risk level and the knowledge that is recorded in the model;
- Different appearances of one threat-group (e.g. DDoS attack) should be modelled separately. This seems tedious, but for one group of threats, a large part of the model will be the same for all appearances (only some nodes will be specific for an appearance) and many information sources and decision tables can also be re-used;
- One of the challenges was to collect relevant information sources, that are also available when needed. This will remain to be a difficult task, because the information needs to be collected from different parts of the organization and, probably, also externally;
- Also challenging is the translation from information to probability. We have experienced that it helps to define translation tables in terms of maturity levels (is it a one-off, it is done more frequently, is it described, is it structurally done according to the description). But also presence of certain information elements can be used for translation tables (e.g. if we have only 7 of maximum 10 information elements present, we assume effectiveness to be 70%). This needs to be considered from case to case and put into context.

All in all, the method can be well used in practice, both in actual risk management but also for different analysis purposes and we think the effort that is needed to build the models is worth it. As a next and final step we plan to enhance the methodology and its guidance and automated tooling. so it will become usable for employees in risk management processes.

Our methodology provides traceable, modelled risk estimations based on the current insights. Yet in practice there is an ongoing dynamic dialogue between attacker and defender where both are struggling for the weakest link. The attacker is focused on its exploitation and the defender on avoiding that. This means that both attacker and defender are observing each other and over time they improve their way of attacking or defending based on their observations. This dynamic complex behavior caused by attacker – defender interactions and response of the (resilient) organization [Zeijlemaker], [Zeijlemaker2] will cause the input parameters to increase or decrease over a longer time period. Therefore there is at least a need to do regular risk estimations.

There is dynamic complex behavior caused by attacker – defender interactions which causes the input parameters to change over time.

More information

More information and a more detailed description of the model can be found in the white paper 'Quantifying risks' will be published on the SRP cyber security webpage: https://www.tno.nl/srpcybersecurity

Bibliography

[Cooke]
R. M. Cooke, Experts in Uncertainty: Opinion and Subjective Probability in Science, New York, USA: Oxford University Press, 1991.

[Wisse]
B. W. Wisse, N. P. Elst van, A. I. Barros and S. P. Gosliga van, "Relieving the elicitation burden of Bayesian Belief Networks," in BMA, 2008.

[Phillipson]
F. Phillipson, E. Matthijssen and T. Attema, "Bayesian belief networks in business continuity," Journal of Business Continuity & Emergency Planning , vol. 8, no. 1, 2014.

[Phillipson2]
F. Phillipson, I. C. L. Bastings, and N. Vink, "Modelling the effects of a CBRN defence system using a Bayesian Belief Model.", 9th Symposium on CBRNE Threats, Helsinki, Finland, 2015.

[Zeijlemaker]
Zeijlemaker S, 2016. Exploring the dynamic complexity of the cyber-security economic equilibrium, PhD colloquium of the 34th International Conference of the System Dynamics Society, Delft, Netherlands, July 17–July 21

[Zeijlemaker2]
S. Zeijlemaker, 2017, Exploring the dynamic complexity of the cyber-security: does a deeper understanding support financial policy evaluation?, PhD Research Proposal, March 2017, Radboud University

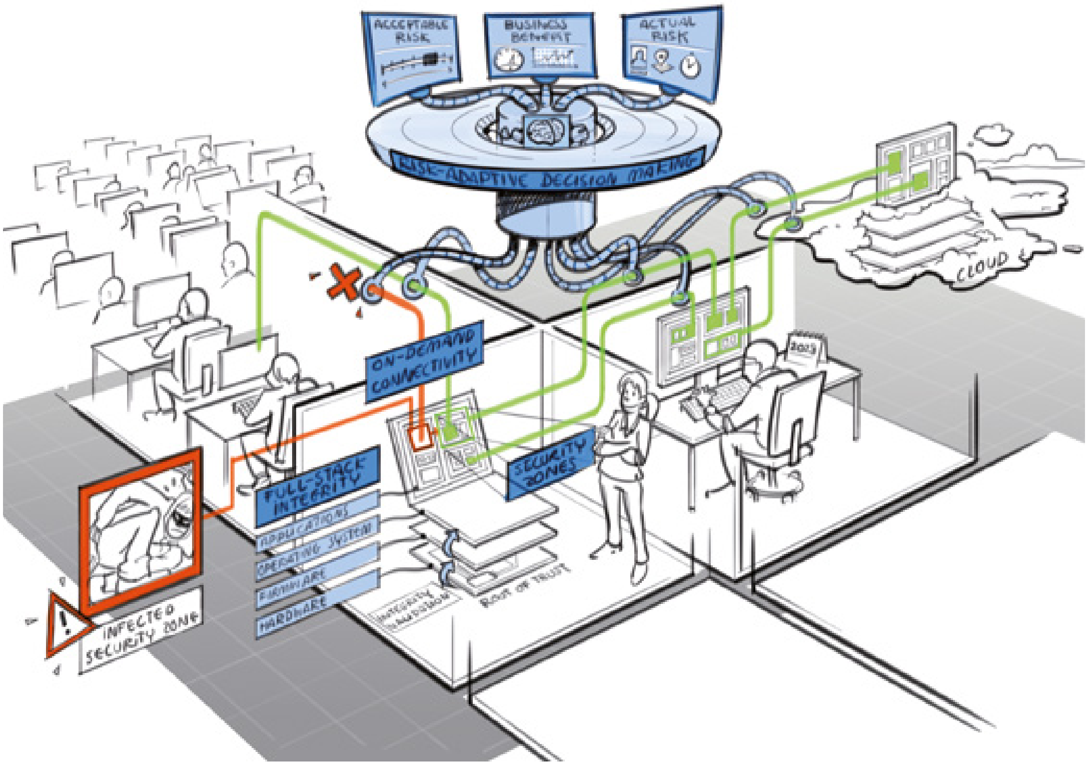
> “Security is a strategy enabler for our digital transformation. The Shared Research Program fits perfectly in our ambition to be customer relevant and trend setting, were we collaborate to make Information Technology safer through innovation in cyber security technologies and processes. We’re extremely enthusiastic about the research work on “Quantifying Cyber Risk”. This research project aims to develop and evaluate a methodology to quantify cyber risks based on actual (available) and dynamic data like security monitoring information. Risk quantification and modeling is part of our insurance DNA and very relevant for not only (internal) security and risk management organizations, but also further development of cyber related insurance propositions.”

Willem van der Valk
GISO Achmea

Advanced Security Architectures - Don’t trust. Verify!

Hiddo Hut (TNO), Wouter Langenkamp (TNO), Martine Kea (ABN AMRO), René Sibbel (ABN AMRO)

Can we think of and design new security concepts for the future?



Breaking the cycle

Cyber security threats targeting the financial industry continuously evolve into new forms of attacks. As a consequence, security measures that defend systems and services against these attacks are also evolving over time. This evolutionary process is driven by constant innovation in the areas of cyber-crime prevention, detection and response. However, this continuing cycle of attack and defend requires a great deal of human effort and time. Can we break out of this cycle? Can we think of and design new security concepts for the future? Are the new concepts good enough to protect us for a few years’ worth of iterations of attacks?

In the SRP, security consultants, engineers and architects have worked together to design a security architecture in which new innovative security concepts are proposed that can be used to escape from the ongoing arms race: the Advanced Security Architecture (ASA).

Based on our analysis of published banking cyber heists like Carbanak[1], Barclays[2] and the Bangladesh[3] Robbery we extrapolated some of the problems that allowed these heists to be successful:

1. **Eggshell**. Current architectures are frequently based on the Eggshell model, where the internal network is protected from the outside world by shielding it using a security perimeter. The problem is that, once inside, an attacker has the ability to move through the system. As the threat landscape has evolved, a strong perimeter defence on its own is no longer good enough.
2. **Vulnerabilities**. Attackers make use of (combinations of) vulnerabilities that are present in computing environments such as servers, workstations, mobile devices, networks and

[1] https://media.kasperskycontenthub.com/wp-content/uploads/sites/43/2018/03/08064518/Carbanak_APT_eng.pdf

[2] https://www.dailymail.co.uk/news/article-2612285/Acid-House-King-handcuffed-Jonathan-Ross-jailed-sophisticated-cyber-bank-heist-skimmed-1-25-million-accounts.html

[3] https://en.wikipedia.org/wiki/Bangladesh_Bank_robbery

services while at the same time also exploiting weaknesses in people, processes and organizations. Vulnerabilities will always be present, even more so due to the ever-growing IT landscape. We need to find a better way to handle these weak spots without being overly dependent on vendor patches.

3. **Trust**. Today's successful companies have morphed into complex environments with lots of employees, customers, suppliers and partners that continuously demand new forms of access to data and functionality using an ever-expanding array of devices and networks to do so. There is too much trust in these environments and not enough proof that systems are secure.
4. **Static**. Security architectures and the security measures therein consist of many statically defined elements that make it hard to keep up with the increasingly dynamic environment. The classification of cyber security risks into actionable and quantifiable responsibilities for people, systems, networks and services requires a lot of human interaction and decision-making from higher up the chain of command.

Note that the identified problems are of a generic nature, i.e. they are not specific for the financial industry and could be applicable to many organizations.

A changing paradigm

The goal of ASA is to propose a redesign of security architectures to change and improve the way in which security attacks can be mitigated. The context we have chosen is (a) a generic 'greenfield'[4] situation and (b) a time-frame of about 5-10 years ahead. Both aspects allow us to look beyond today's solutions and limitations in order to truly think of something new that has not been done before. In that time span, commercial products should be available on the market to implement (parts of) the architecture. As a consequence, this means that the developed concepts do not form a complete and all-encompassing security architecture that spans an entire organization. In fact, some of today's current security measures work quite well and should, in our opinion, not be discarded.

All of our ideas are centered around a changing paradigm of "Don't trust. Verify!". The underlying assumption is that with today's evolving security attacks, infrastructure and functionality can no longer be trusted up front. Before being allowed to be used for sensitive workloads like financial applications, we want a higher degree of assurance; we want infrastructure, functionality and users to be verified explicitly and continuously. We thereby assume that the hardware and software stack of computing cannot be trusted. We assume that the network cannot be trusted. We assume that applications and services cannot be trusted. In other words, every part of the architecture may have vulnerabilities that can potentially be exploited at some point in time.

We have to come up with a recipe that can deal with this brave new world. Not by preventing cyber security incidents from happening – we have already lost that game – but rather by creating an architecture in which those events can only create small, localized problems. We have to be able to contain attacks in order to prevent escalation and diminish the overall impact. We need a solution that does not care if something, somewhere turns 'red'. We want to be able to shrug it off and say: "It's just a flesh wound".

Proposed concepts

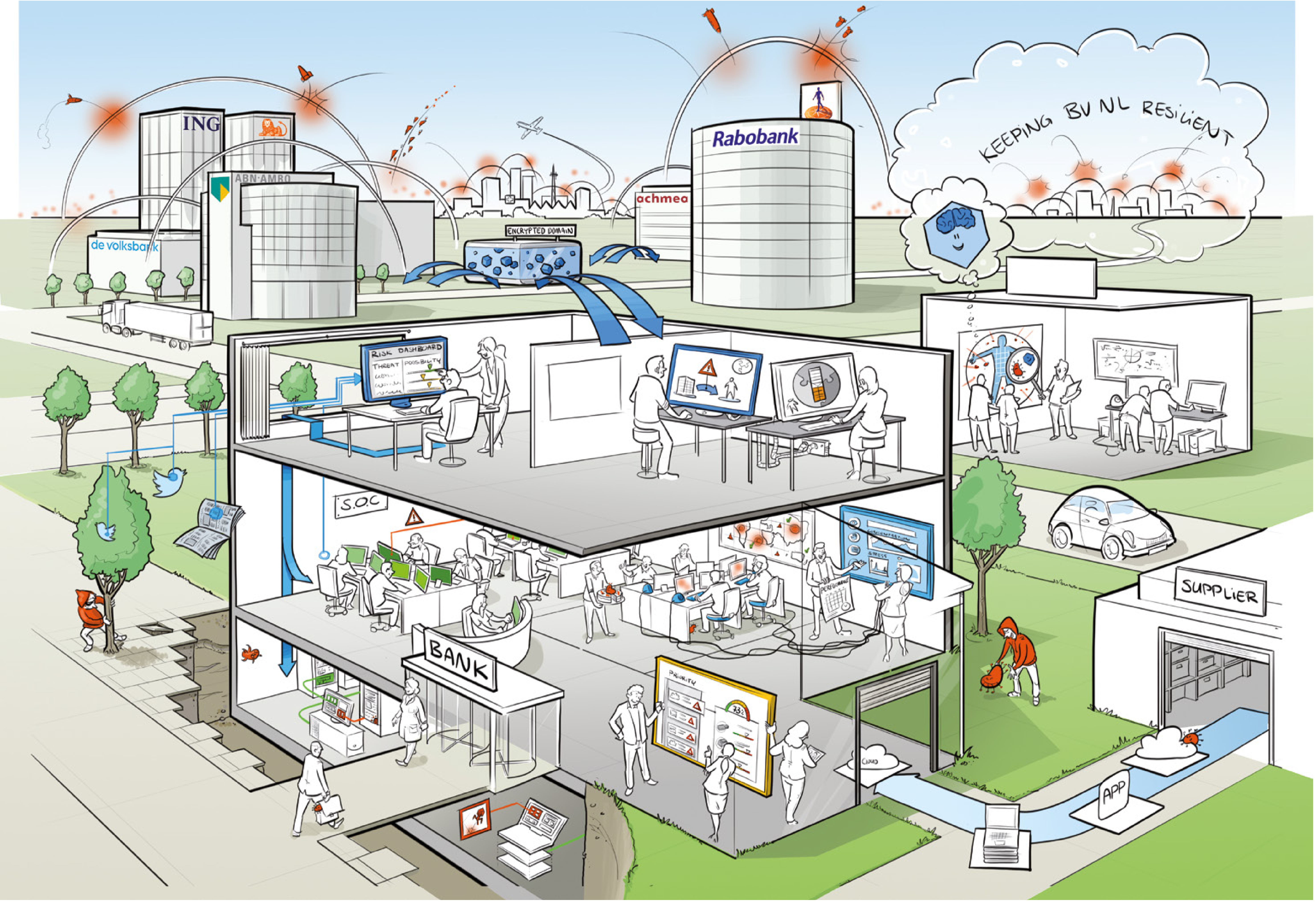
Hereafter follows a summarized overview of a selection of concepts that we propose to be integrated within the newly designed security architecture. The premise of every concept is given, followed by a brief technical overview and an explanation of how these will contribute to the overall architectural design.

Security Zones

Security zones is a concept which aims to define clear boundaries and interfaces between different (sets of) functionalities, thereby allowing these functionalities to be compartmentalized.

Security zones are a way of reducing the attack surface and preventing the escalation of attacks.

[4] 'Greenfield' means no legacy and not taking into account existing IT infrastructure.


ING
ABN·AMRO
de volksbank
Rabobank
achmea
ENCRYPTED DOMAIN
KEEPING BV NL RESILIENT
RISK DASHBOARD
THREAT
POSSIBILITY
S.O.C
STRESS
PERFORMANCE
BANK
PRIORITY
SUPPLIER
CLOUD
APP

On-demand connectivity makes connections explicit and insightful, both reducing the amount of unwanted connections as well as making it easier to monitor them.

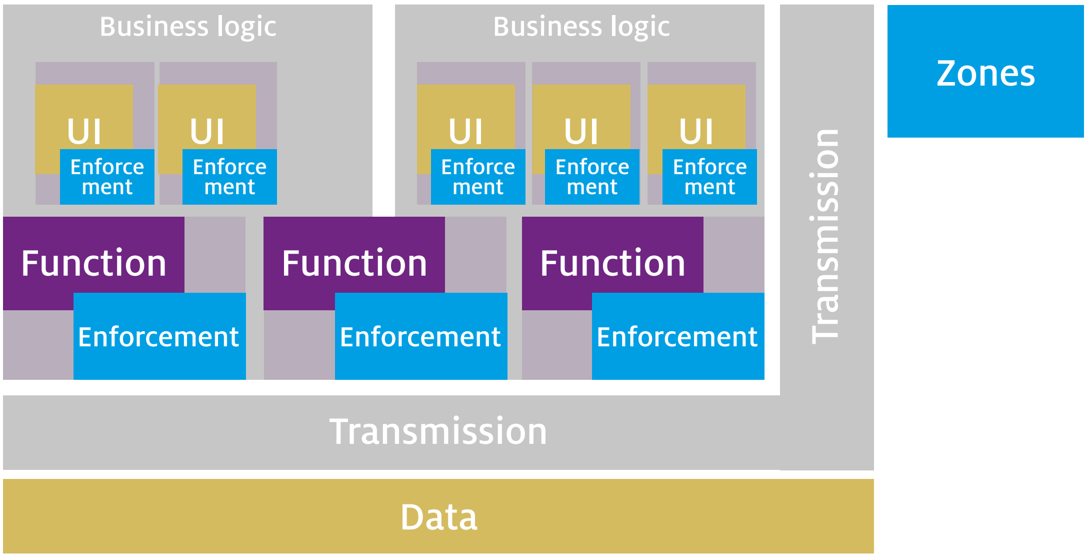


Figure 1: Security zones

Compartmentalization is the act of splitting an architecture in more manageable sections of functionality. Amongst other benefits, this enables the containment of malicious activities, rapid (re)deployment, reusability, better version control and an immutable infrastructure. These compartments – denoted security zones in ASA – are strictly isolated by default unless explicitly instructed otherwise. Security zones can be designed to be immutable, meaning the zones themselves are never reconfigured but completely replaced with a new version of the security zone. Security zones may also be used to contain or mitigate malicious threats by both reducing the attack surface (as only specific parts of an architecture will be exposed to an attacker at a given time) and containing malicious activities within a zone (as an attacker will have only limited possibilities for moving laterally). As part of the concept, each security zone is bundled with its own set of security requirements, which have to be met in order to interact with it. The responsibilities to maintain these requirements and enforce them in practice should be clearly appointed to a responsible entity. Security Zones is a novel concept that builds upon and combines aspects of existing techniques (e.g. compartmentalization [1], segmentation, microservices [2, 3] and networked risk management [4]).

Security zones are a way of reducing the attack surface and preventing the escalation of attacks in an eggshell type of environment. While security incidents may still take place, this ensures that their impact will be minimized.

On-Demand Connectivity

On-Demand Connectivity is a network mechanism in which authorized connections between two entities must be provisioned in order for them to be able to communicate.

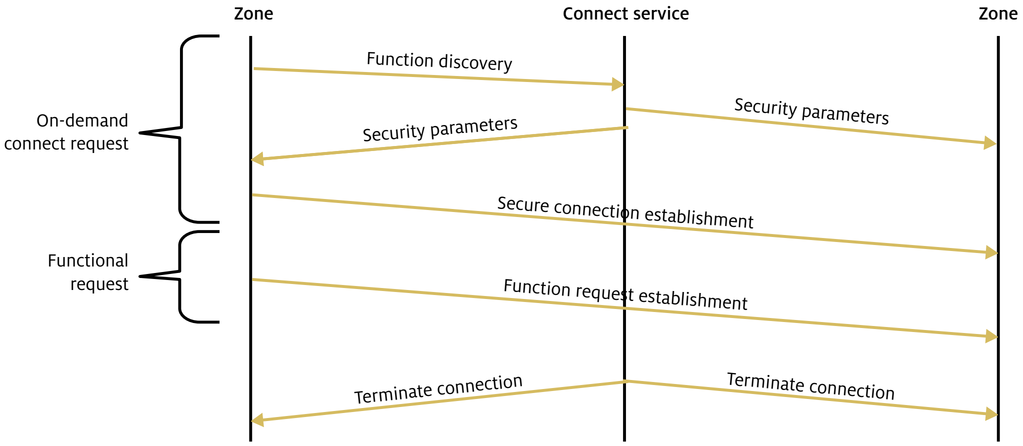


Figure 2: On-Demand Connectivity

[17] This capability encompasses activities such as acquisition, maintenance and release management for software solutions and other technical infrastructure employed in the organization's CTI practice.

This idea aims to ensure that there are only connections made between functions in the network that are actually necessary for business applications. The consequence is one of Zero-Trust: without provisioning, there is no per default communication possible. To make sure that keep-alive messages do not keep connections alive indefinitely and create a form of network legacy, we also propose a 'garbage collector' mechanism that automatically tears down connections. On-Demand Connectivity is an existing concept [5] for which we developed a novel implementation to validate the idea and research and demonstrate its functionality.

This concept addresses the eggshell problem by adding a Zero-Trust type of network to a strong perimeter defence. On-demand connectivity makes connections explicit and insightful, both reducing the amount of unwanted connections as well as making it easier to monitor them. This drastically reduces the impact of a security breach, as it will be far more difficult for an attacker to laterally move throughout the system.

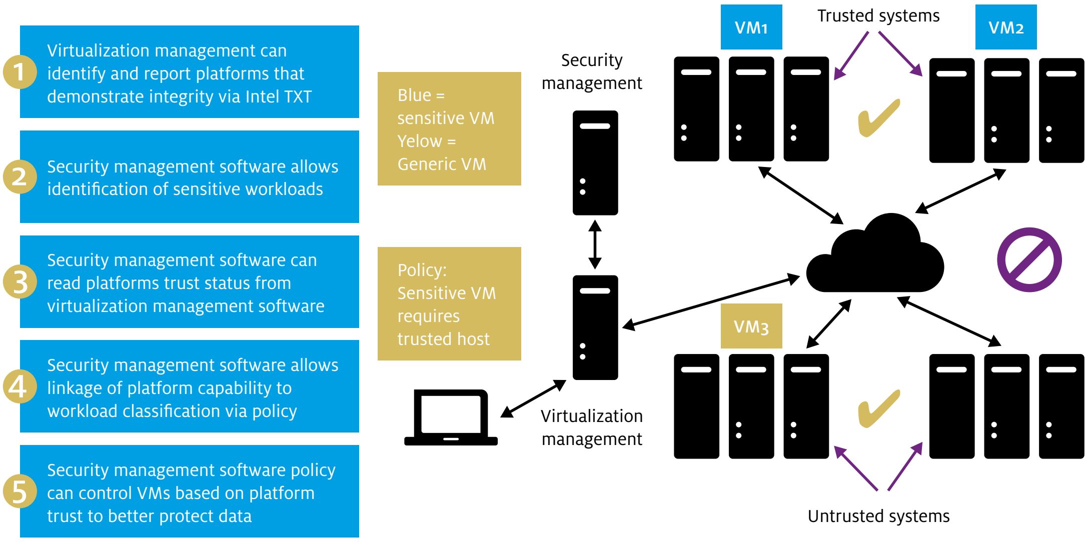
Full-Stack Integrity

Full-Stack Integrity is a hardware-based security mechanism to cryptographically validate the integrity and authenticity of a software stack from the low-level firmware up to and including application-level functionality.

In its most common form, a general computing platform consists of a hardware layer, an operating system layer and an application layer. The security of upper layers build on top of the ones below. All of these layers are however sensitive to security issues: when one of the lower layers is insecure, all layers above are affected. We propose a hardware-based Security Trust Anchor that is completely out of reach from the Operating System and the applications. Next we propose a remote attestation mechanism using a security trust anchor over critical components in the stack (e.g. BIOS (Basic Input/Output System), bootloader, kernel, base operating system image, hypervisor and application). This enables a remote system (challenger) to asynchronously measure the current status of integrity and authenticity of the platform of another system to determine the level of trust. Next we propose using such a mechanism to migrate sensitive applications and services away from an untrusted cluster to a trusted cluster within the scope of a single cloud-provider if the integrity of a cluster cannot be guaranteed anymore. Finally we propose using such a mechanism to migrate sensitive applications and services between different cloud-providers in the case of a large-scale emergency. Our Full-Stack Integrity concept is based on existing ideas [6] but with additional requirements (e.g. open firmware for higher assurance and independent security evaluation) and additional security mechanisms (e.g. migration of functionality).

This concept addresses the vulnerability problem and makes an organization less dependent on vendor patches because it focusses on trying to detect unauthorized changes. It also addresses the eggshell problem by reducing the opportuni-

Prove your trust-level by producing a valid chain of attestations.



1 Virtualization management can identify and report platforms that demonstrate integrity via Intel TXT

2 Security management software allows identification of sensitive workloads

3 Security management software can read platforms trust status from virtualization management software

4 Security management software allows linkage of platform capability to workload classification via policy

5 Security management software policy can control VMs based on platform trust to better protect data

Figure 3: A hardware-based security mechanism to determine trustworthiness
Source: https://software.intel.com/en-us/articles/intel-trusted-execution-technology-intel-txt-enabling-guide

The goal is to move from statically defined rules and environments to a more dynamic system that can adapt to a changing environment.

ties as well as impact of a piece of malware and adds a strong integrity and authenticity detection mechanism to the mix.

Risk-Adaptive Decision Making

Risk-adaptive decision making is a concept in which decisions are made based on a trade-off between current risks, acceptable risks and the need for the requested action. By making these actions explicit and measurable, such a system can be used to support or even automate parts of decision making.

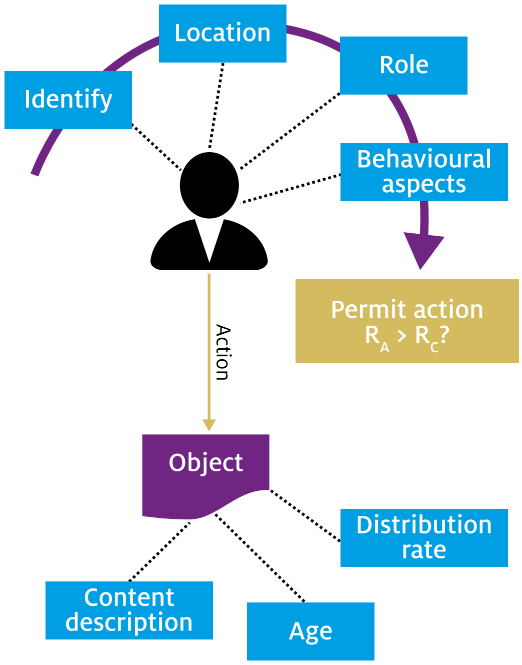


Figure 4: Risk-Adaptive action evaluation

The idea originates from risk-adaptive access control (RAdAC) [7], which is a method of providing access according to a risk trade-off. In contrast to only making an access decision, risk-adaptive decision making strives to more universally apply such trade-offs in the architecture. The use of risk-engines to support decision making is not a new concept and is already being used to reduce manual efforts, improve accuracy and enable automation. However, many of today's systems only apply to a narrowly defined problem and are designed according to a predefined set of rules. We aim to more universally apply the concept of risk-adaptivity throughout the infrastructure, where it can more generally help decide whether or not an action should be allowed. Both of these concepts require a system in which requirements, measures, demands and decisions are made more explicit. In order for a system to reason about such features independently, we will need to come up with a system language to describe them. The transparency and explicitness of requirements and decisions provide a unique platform for monitoring and detection as well as user behavior analysis. The goal is to move from statically defined rules and environments to a more dynamic system that can adapt to a changing environment.

This concept makes a security architecture more dynamic instead of static. It also addresses the trust problem by creating a more transparent decision making process that is not as dependent on human interaction.

Results

The results of ASA cover a wide range of proposed solutions of which a selection is presented in this article. Our approach has been to analyze three financial cyber-heists, extrapolate the problems underneath the attacks that allowed them to do what they did and find ways to mitigate these problems.

For the concept of 'On-Demand Connectivity', we implemented a working proof-of-concept. It is built on existing open-source technology and aims to present a Zero-Trust perspective of the network to any infected device, software, service or a malicious user. For this concept, we envision a future where every connection over the network between two components has to be authorized explicitly, in order to limit lateral movement and improve monitoring and detection capabilities.

Future work

As a next step, we would like to study the technical feasibility of (a subset of) the other proposed components by building more proof-of-concepts. Additionally, we would like to replay the cyber-heists and their malware in a controlled environment in which (a subset of) our concepts are deployed, to see how they deal with these kinds of attacks. Last but not least, we would like to consult vendors to disseminate our results and to verify whether any of our proposed concepts are included in future roadmaps.

Bibliography

[1] Robert Watson, Steven J. Murdoch and others (March 2013). “Towards a Theory of Application Compartmentalisation”[5]. University of Cambridge, SRI International and Google UK Ltd.

[2] Nathaniel Schutta (January 19, 2018). “Should that be a Microservice? Keep These Six Factors in Mind”[6]. Pivotal.

[3] Andy Wu (2017). “Taking the Cloud-Native Approach with Microservices”[7]. Magenic.

[4] Joosten, H., & Smulders, A. (2014). “Networked Risk Management : How to successfully manage risks in hyperconnected value networks”[8]. TNO.

[5] Armon Dadgar. “The What, Why, and How of Zero Trust Networking”[9]. HashiCorp.

[6] Philip Tricca (2018). “TPM 2.0 Software Stack: Usability, Privacy and Security”[10]. Intel.

[7] MCGRAW, R. (2009). “Risk-adaptable access control (radac)”. In: Privilege (Access) Management Workshop. NIST–National Institute of Standards and Technology–Information Technology Laboratory.

[5] See https://khilangudka.github.io/pubs/2013spw-compartmentalisation.pdf

[6] See https://content.pivotal.io/blog/should-that-be-a-microservice-keep-these-six-factors-in-mind

[7] See https://cloud.google.com/files/Cloud-native-approach-with-microservices.pdf

[8] See http://publications.tno.nl/publication/34612233/jfvm8m/joosten-2014-networked.pdf

[9] See https://www.hashicorp.com/resources/how-zero-trust-networking

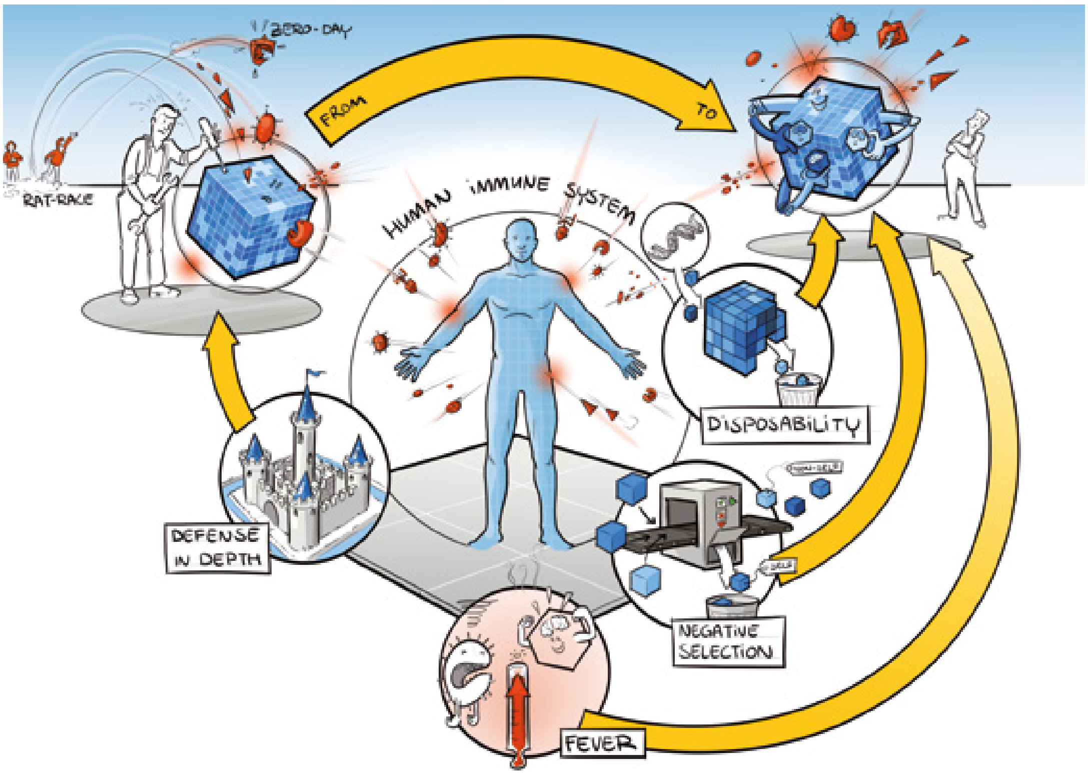
[10] See https://www.platformsecuritysummit.com/2018/speaker/tricca/

> “ Security measures should at least keep pace with ever evolving cybercrime threats. Traditional rule-based detection is no longer sufficient. Effective detection of threats calls for smart anomaly based detection. The Shared Research Program increasingly not only researches this topic but also develops implementation ready smart capabilities in the area of f.i. Phishing, prioritizing SIEM alerts, DNS Ninja. Participation in these projects makes us learn and gets us inspired and able to improve our capabilities by creating advanced models for early detection.”

Beate Zwijnenberg
CISO ING

How Biology can help us to protect against cyber criminals: self-healing security

Bart Gijsen (TNO), Frank Fransen (TNO), Frank Schuren (TNO), Rogier Reemer (Achmea), Shairesh Algoe (ABN AMRO), Paul Samwel (Rabobank), Bert van Ingen (Rabobank)



How to break the cyber attack-defense rat race?

Introduction

Cyber security technology has matured strongly in multiple areas of expertise, including cyber threat intelligence, monitoring and detection, resilience, predictive analytics and automated response. Simultaneously, cyber attacks have also evolved in a continuous race to outsmart the maturing cyber defense measures. This race consumes increasing man power and other resources, in particular on the defense side, which raises the question how to break this vicious circle.

This inspired the SRP (Shared Research Program) partners and other researchers to look at other domains that are caught up in a rat race. Inspiration may be found in the human immune system and the way in which it is coping with the threat of mutating viruses, bacteria, fungi and parasites that are continuously attacking human bodies. Exploration of the parallel between the human immune system and cyber defensive strategies provides useful inspiration for innovative developments towards self-healing for cyber-security.

We investigated the state-of-the-art and analyzed the parallel between the human immune system (HIS) and cyber defense strategies. This was done by a mix of cyber security and biology experts

Self-healing security research seems more promising than its limited practical application suggests.

from the SRP partners. Also, external speakers from Delft University of Technology and VU Amsterdam were invited to present their research on distributed artificial immune systems and on self-healing software. This article presents the insights gained in the analysis on Self-Healing for Cyber Security (SH4CS).

Evolution of self-healing

The term ‘self-healing’ was first coined by IBM in 2001 and more elaborately defined in their article titled “The dawning of the autonomic computing era” [1]. According to the authors autonomic computing comprised eight characteristics: self-awareness, -configuring, -optimization, -healing, -protection, context-awareness, openness and anticipatory. In their definition self-healing systems should be able to recover from a failed component without any apparent application disruption, with the objective to keep enterprise applications available at all times. While this definition of self-healing is focused on availability, self-protection is focused on authorized access to computing environments, or cyber systems. In this article we refer to SH4CS as the broader definition of self-* (in which the asterix depicts any term that is used in this context, such as self-healing, self-configuring etc.) characteristics that are applied to autonomously secure cyber systems (i.e. not requiring any human interaction or modification).

Part of the vision of autonomic computing is a high-level concept for engineering self-* systems [2], which has remained a consensus technique for automated monitoring & control until today. This self-* engineering technique is a specialized MIMO (multiple input, multiple output) closed-loop control system and referred to as MAPE-K: Monitor, Analyze, Plan and Execute, using Knowledge. In Figure 1 the MAPE-K control loop concept is illustrated.

Autonomic computing and MAPE-K (alike) concepts inspired the field of self-adaptive (software) systems (SAS). In 2013 over a hundred papers about self-protecting software systems (more commonly referred to as SAS) where included in a survey [3]. The categorization of these papers in this survey resulted in a taxonomy that distinguishes between:

a) *why* SAS is applied (e.g. to adapt to changes in context or available resources),
b) *which* software or IT layer it is applied to (e.g. application, operating system, (virtual) resource or communication layer),
c) *when* it is applied (proactive or reactive),
d) *what* it modifies (e.g. parameters, code, alternate service) and
e) *how* it makes its adaption decisions (e.g. system internal / external, centralized / decentralized, rule- / goal- / utility-based).

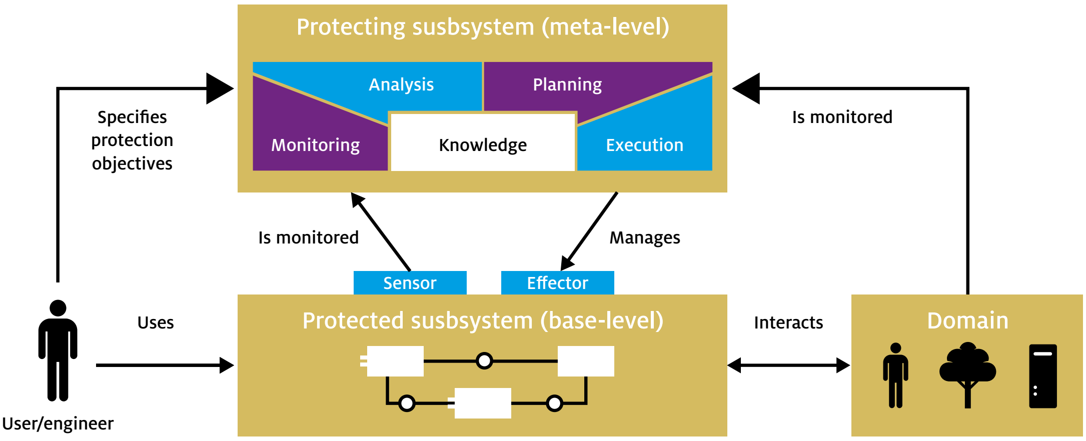


Figure 1: A MAPE-K engineered self-protected subsystem; source: [3]

Until recently the least explored part in SAS has been the decision making process; i.e. the steps of analysis and planning in the MAPE-K loop. For the SAS decision making part techniques are emerging in the field of Cyber Reasoning Systems (CRS) [4]. CRS are expert systems aimed to automatically detect exploitable bugs, generate verifiable exploits and patch software. In recent years this field has started to make progress, amongst others boosted by DARPA's Cyber Grand Challenge in 2016, in which seven high-performance autonomous computer systems competed to patch and hack software in tens of battle rounds. Nevertheless, CRS research is still in its infancy.

Parallel between HIS and AIS

At the beginning of the self-healing evolution IBM deliberately chose a term with a biological connotation, hinting at the parallel with the autonomic nervous system [2]. In our SH4CS analysis we also found that bio-inspired security provides a fresh viewpoint. In particular, the parallel between the human immune system (HIS) and artificial immune systems (AIS, a term that emerged in the mid 80's). Artificial immune systems are adaptive cyber (security) systems, inspired by human innate and adaptive immune functions and principles, that protect against vulnerabilities and facilitate recovery from their exploitation.

In the next section we attempt to describe the parallel between the HIS and the AIS as far as possible. We do so by proving a mapping between elements and characteristics of the HIS and AIS and to identify commonalities. While doing so it is also clear that there are differences between the HIS and AIS.

Mapping and commonalities

For the mapping between the HIS and the AIS we start by identifying the 'to be protected system'. The HIS can be regarded[1] to protect the human body that it is part of, which is a confined system. The equivalent of a human body in AIS seems to be less clear. In the early days of the information era a stand-alone 'computer system' or 'information system' was a clear candidate as the system to be protected. However, nowadays IT systems and applications have become intertwined and shared, within organizations and even between organizations via the internet. In [5] this current state is referred to as cyber infrastructures that have "no sense of self-awareness". In this blurry context we chose the following (ambiguously defined) to-be-protected-system for the AIS: all IT systems and applications used by, and under the responsibility of, a single organizational unit that governs the cyber security policy (i.e. there are no competing AIS's that may enforce conflicting security actions).

The 'objective' of the HIS could simply be referred to as the survival of a human's body. The most commonly referenced AIS objective is the information security triad: CIA (Confidentiality, Integrity and Availability). Note that the CIA triad is applicable to information, communication and data security. Regarding the security of the underlaying network and IT systems the confidentiality objective can be interpreted as controlled system access (related to identification, authentication and authorization).

Bio-inspired security provides a fresh viewpoint, but there are also differences between the HIS and AIS.

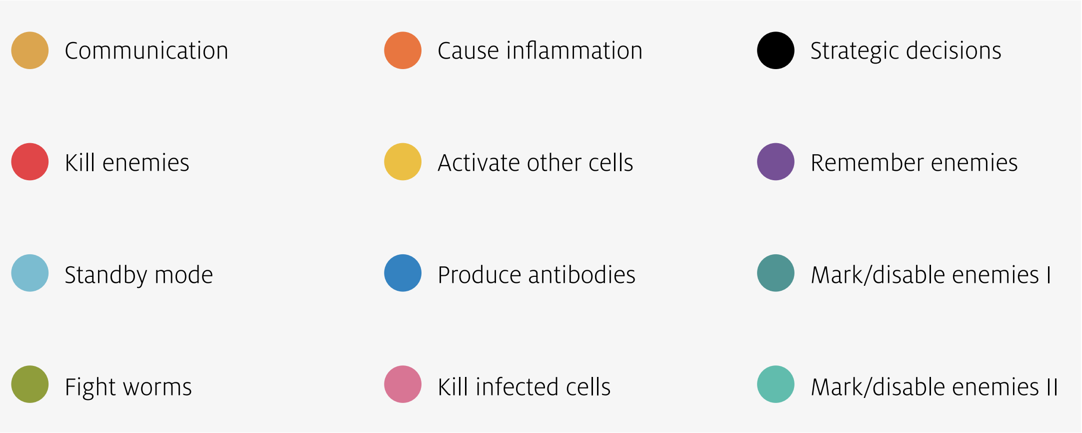


Figure 2: 12 jobs of the human immune system [6]

[1] Note that there can be different viewpoints to this when looking at diversity of the HIS between individuals, which protects a population instead of individual bodies. Likewise, when considering the long-term evolution of the HIS this evolution has protected the entire human race. In this paper the focus is on the human body as the system protected by the HIS.

In the much younger research field of cyber security the list of defensive measures is less clearly defined.

The ‘defensive measures’ that can be applied by the HIS to combat invaders in the human body are presented in Figure 2. This set of 12 jobs is the result of decades of HIS research that are further illustrated in the animated movie [6]. In the much younger research field of cyber security the list of defensive measures is less clearly defined and subject to change. High-level cyber defense measures include: hygiene (software scanning and network filtering rules, up-to-date patches, etc.), reducing the attack surface (hardening), cyber monitoring and intelligence (user behavior analytics, anomaly detection, threat intelligence, etc.), deception techniques (e.g. honey pots) and techniques to throttle exploitation. In the SH4CS analysis much of the discussions were focused on identifying commonalities and gaps between defensive measures of the HIS and AIS. Some of the identified (partial) commonalities are included in Table 1 (this is a non-exhaustive comparison of defensive measures, more can be found in [5] and [7]).
When looking at the attack side of the rat race we can distinguish several **types of attackers**. The HIS has four types of non-self attackers: bacteria, viruses, fungi and parasites. Besides these non-self attackers there are diseases that are typically not regarded as HIS attackers, such as cancer and anti-immune diseases. In the parallel with AIS, Intel’s threat actor library [8] distinguishes twenty-one types of cyber attackers. Examples are: thief, civil / radical activist, competitor and sensationalist. This includes inside-attackers (self), such as a disgruntled employee or an internal spy, as well as outside attackers (non-self).

The high-level ‘**objective of the attackers**‘ is self-preservation. In more detail the cyber threat actor library [8] distinguishes the objective of an attacker in the intended outcome (theft, business or technical advantage, damage and/or embarrassment) and the intended action (copy/take, destroy/damage, deny access or multiple of these). For HIS attackers the ‘intended outcome’ is more or less the growth of their population. The ‘actions’ they take to achieve that are feeding and reproducing. While doing so they cause collateral

HIS defensive measure	AIS defensive measure
Macrophages (Greek for big-eaters) are white blood cells that provide generic defense by (not very selectively) cleaning up damaged cells and ingesting non-self pathogens. They can also initiate specific defensive measures by the adaptive immune system.	We did not identify automated cyber defense measures that are as generally applicable as the role that macrophages play in the HIS. Their function is common to that of an array of cyber defensive measures including intrusion, anomaly and malware detection and antivirus, complemented with human analyst intelligence.
Natural killer cells that selectively kill infected cells that are (a) not revealing “self” markers or (b) are revealing “danger” signals.	In theory, remote attestation can be used in IT systems (e.g. via mobile agents) that inquire running software code to identify themselves using Trusted Platform Module (TPM)[2] hashes (and kill them, if not responding or not valid). However, this is not common practice yet.
Memory B cells enable fast immune response in case of re-infection. In combination with vaccination, memory B cells can be made an infection preventive measure.	Antivirus scanners use virus signature dictionaries that have a common function as memory B cells, where distribution of dictionaries by antivirus vendors is similar to vaccination.
Inflammation is a response to an infection that eliminates the cause of cell injury, clears out damaged cells and initiates repair.	We did not identify a clear AIS commonality for inflammation.

Table 1: Comparison of several defensive measures.

[2] Trusted Platform Module is an ISO standard that specifies cryptographic verification of the integrity of a HW/SW stack.

damage to the bodies they feed from and over time these invaders mutate and build up resistance.

Regarding '**attacking phases**' a number of stages can be distinguished[3]: preparation / infection / spreading / exploitation. Where these phases fit well for the cyber kill chain (AIS), some imagination is required to fit in the HIS attacker stages. Except for evolution of bacteria (that can become resistant) and virus mutations there is not an explicit preparation phase. Also, there is no explicit exploitation phase for HIS attackers, since self-preservation by growing in population (i.e. the spreading phase) is their intended outcome.

Differences

While this parallel inspires and brings forth suggestions to improve and extend current cyber defense techniques, we also observe differences. These differences may illustrate more fundamental aspects that we need to change in our current way of designing and securing information systems. For that purpose we highlight three of the most fundamental differences.

A fundamental aspect of the HIS is the fact that large numbers of more or less identical human cells collaborate in performing body functions. As such, individual cells are **disposable** and are continuously regenerated. This feature is not common in IT environments: applications can typically not be killed at will and randomly deleting data files may lead to unrecoverable information. Nevertheless, some concepts such as virtualized, micro services and serverless architectures and CI/CD (Continuous Integration and Continuous Delivery) techniques are enabling IT infrastructures to become more disposable and regenerative.

Secondly, the HIS is **decentralized and choreographic** by nature with multiple, redundant biological systems that provide overlapping protective functions (for which the interactions between them still remain a mystery). In contrast to this, cyber security architectures and SOC's tend to be centrally orchestrated. Moreover, most current cyber security solutions are information systems that provide an overview to humans to assist them in their cyber decision making. While human brain capacity applied to centralized data sets might currently be unmatched for interpreting complex cyber situations and acting upon it, advances in distributed computation may relieve the human effort. During the SH4CS analysis an AIS prototype was presented that implements negative selection-based anomaly detection[4] in large IT infrastructures using adaptive, choreographic deployment of distributed, mobile agents.

It makes sense to complement current centralized cyber defenses with decentralized, self-adaptive security measures.

Related to the above another distinction between HIS and AIS is that the HIS is adaptive by nature, while AIS are planned, developed and managed [5]. The latter is a consequence of the common approach to build cyber security technology using the same IT building blocks that are used to build the systems that they are supposed to protect. Note, that for business IT systems it is essential that one can plan, develop and manage specific functionality for supporting business processes. This approach is also useful for implementing cyber monitoring & control technology. However, emerging agile and dev(sec)ops approaches are inherently needed to provide adaptivity of current cyber technology in order to enable adequate response to unprecedented attacks.

Lessons learned

In our SH4SC analysis we experienced that discussing bio-inspired security in a mixed group of cyber security and biology experts provides a fresh viewpoint. In particular, from discussion of the parallel between the human immune system (HIS) and artificial immune systems (AIS) we learned the following lessons:

a) Centralized orchestration of security monitoring, prevention and resilience is dominating nowadays cyber security measures, while the HIS is organized as a decentralized choreographic protection system. Both approaches have their pro's and con's. While centralization provides administrators and security officers overview and control, it also provides attackers a source of intelligence and a target to collect privileges. It seems to make sense to complement current centralized cyber defenses with decentralized monitoring and control that is also capable of adapting itself autonomously within certain cyber security objectives and policies. Introducing self-adaptiveness in IT architectures is a challenging task, where research in the field of cyber reasoning systems seems to be promising.

[3] The exact kill chain phases evolve over time since attackers are increasingly using pre-packaged attack tools.

[4] The HIS-inspired negative selection process can be applied to generate new traffic patterns for filtering yet-unknown 'non-self' traffic, which patterns are not triggered by 'self'-traffic.

Self-healing security provides novel approaches to becoming "the cyber fit-test".

b) "Self-awareness" and the ability to distinguish between "self and non-self"[5] entities and activities are important features in HIS protection strategies. These properties were also pointed out as key elements of autonomic computing [1] and required to develop self-healing and cyber reasoning systems. Although attempts are being made to develop machine processable protocols for distinguishing self and non-self IT services, software components and hardware elements, their limited adoption is still hindering further development of AIS.

c) The HIS is an example of a multi-layered protection system, similar to defense in depth in AIS. The skin can be regarded as an outer layer protection and the macrophages of the innate immune system as a second layer, that protect against a wide range (non-specific) of attackers, by isolating and destroying the invaders. While doing so the macrophages produce alarm signals that, once many of them are being produced, trigger the adaptive immune system to provide specific counter measures (i.e. the HIS contains a decentralized, continuous scale risk indicating mechanism). The adaptive immune system can be regarded the third layer of defense that can mobilize counter measures from its memory of previous attacks or it can produce specific killer cells and anti-bodies.

d) Interesting is how the HIS uses the negative selection process[3] for producing killer cells and anti-bodies against invaders that the body has never been exposed to before. Some AIS research has explored if and how negative selection (amongst others) can be used to protect against zero-day exploits. This research seems more promising than its limited current practice suggests.

e) Protective HIS strategies (presented in for example [5], [6]) are exploiting the principle of disposability. This makes HIS inspired strategies applicable to stateless parts of cyber infrastructures and less applicable for protecting data integrity or confidentiality. In particular, it makes sense to focus on micro service- and virtualized architectures and CI/CD (Continuous Integration and Continuous Delivery) techniques that enable IT infrastructures to become more disposable and regenerative. A continuously regenerating infrastructure can be an additional defensive measure to limit the maintainable duration of attacker footholds that remain undetected.

End of the cyber attack-defense rat race?

The research question that initiated this self-healing for cyber-security exploration was focused on ways to break the vicious circle of cyber-attack and defense. So, does self-healing break this rat race?

The answer is not a clear yes or no. Yes, self-healing does hold the promise to change the rat race. In particular, it may alter the 'rats' in the rat race, which are currently human cyber security experts that can be assisted to a higher degree by automated, self-adaptive systems. As such, self-healing can significantly reduce the required cyber security effort. No, in the sense that the rat race can be expected to remain to exist once self-healing becomes applied more widely. After all, the HIS and its attackers are also involved in an evolutionary loop of genetic adaptation, virus mutation, bacteria resistance, etc. Moreover, an individual's HIS might also suffer from an auto-immune disease (such as HIV). As such the HIS evolution is a "survival of the fittest" rat race in itself, where the HIS still needs occasional assistance from medical professionals. Nevertheless, we conclude that further research into self-healing for cyber security provides novel approaches to becoming "the cyber fittest".

[5] The ability to distinguish "self and non-self" need not be an either / or assessment (i.e. risk or no risk), but rather a gradual scale that can cope with some room for acceptable risk.

Bibliography

[1] The Dawning of the Autonomic Computing Era, IBM Systems Journal, 2003.

[2] The vision of autonomic computing, Computer Journal, Vol. 36, January 2003.

[3] A Systematic Survey of Self-Protecting Software Systems, ACM Transactions, 2013.

[4] Survey of Automated Vulnerability Detection and Exploit Generation Techniques in Cyber Reasoning Systems, arXiv.org, August 2018.

[5] A Taxonomy of Bio-Inspired Cyber Security Approaches: Existing Techniques and Future Directions, Arabian Journal for Science and Engineering, February 2018.

[6] https://www.youtube.com/watch?v=zQGO-cOUBi6s

[7] Basis immunologie, Workshop IT Security & Immunologie, Achmea, December 2017 (internal document, available for SRP partners)

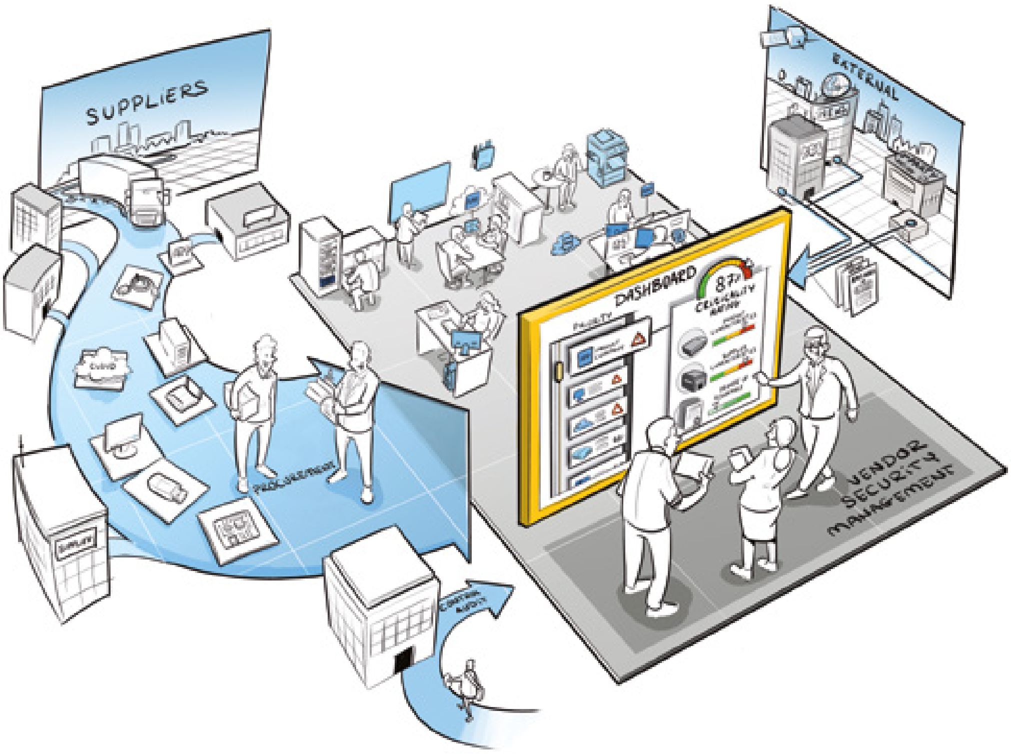
[8] Threat Actor Library, Intel IT threat assessment group, 2007

“ Cybersecurity is increasingly dependent on addressing vulnerabilities across chains and organizations. Cooperative research in this area is challenging but also necessary to facilitate and nurture novel approaches. For the past five years TNO and its partners have co-developed and piloted new approaches in security monitoring and response as well fraud and money laundering detection within the shared research program cybersecurity. TNO as an organization has a long term commitment to foster cybersecurity innovation and especially focuses on developing and prototyping innovations in a demanding collaborative setting. We look forward to continue this successful shared research program with our partners.”

Berry Vetjens
Director Market of Unit ICT TNO

Improving the security assurance of third-party relations

Wouter Langenkamp (TNO), Bob Bekker (ING), Brenda van het Hul (ABN AMRO)



The attention for security starts at the selection of a vendor and continues into the day-to-day operations.

Security in a dynamic world

Security is and always has been a core business for financial institutions. The very nature of financial institutions, working with monetary assets, makes them susceptible to criminal activity. Safeguarding these assets requires continuous, ever ongoing, efforts. This is especially true with the present-day world's digital transformation and overall pervasiveness of ICT; users expect new functionalities, constant availability of trusted information and connectivity from a wide range of personal devices. Keeping up with the functional demands without jeopardizing security is paramount for financial institutions.

In practice, much of the hardware, software and services (hereafter simply denoted as 'products') used to provide these functionalities are supplied by a wide range of external parties from all over the world. This not only creates a functional dependency on these parties, but also drastically influences the way security requirements need to be managed. Depending on the product, security measures may have to be taken by either the external party, the financial institution itself, or both. The attention for security starts at the selection of a vendor and continues into the day-to-day operations.

Achieving assurance is always a trade-off; how much resources should be spent to achieve what degree of assurance?

Gaining appropriate security assurance

There are several ways in which the use of products supplied by third-parties could affect security in an organization. Most significantly, (1) the product may contain security flaws, making it, and the infrastructure it is placed in, vulnerable to malicious activity, or (2) the vendor that provides the product may itself not be trustworthy, either due to some degree of incompetence or even malicious intent. Luckily, in practice, it seems that many of the vendors are well-capable of taking appropriate security measures, nor is there reason to question their intent. However, it is important to make contractual agreements to formally capture the requirements, roles and responsibilities. Security clauses have become common practice; while a standard clause may suffice in some cases, it is oftentimes necessary to tailor these to the specific product and vendor. The requirements may be susceptible to changes over time and thereby require periodic reconsideration. Especially for products used in critical business processes, it is crucial to determine when to take action, as well as to routinely verify whether the contractual agreements are still being met.

Given sufficient time and resources, most financial organizations are well-capable of determining the impact of a to-be-acquired product and the corresponding actions that should be taken. In practice, however, such investigative activities are labor-intensive, whereas available resources are scarce. This makes it unfeasible to do extensive research for every single product that is being acquired and every vendor that is being contracted, thereby also laying restrictions on the actions that can be taken. Therefore, it is important to tailor the use of assurance instruments and the degree of assurance and control to the 'criticality' of the product and the associated vendor (typically, more demands and tighter control for higher criticality). Achieving assurance is always a trade-off; how much resources should be spent to achieve what degree of assurance?

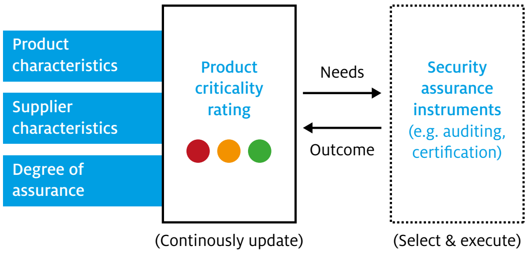


Figure 1: Product criticality rating, formed by the product characteristics, supplier characteristics and the degree of assurance.

Making the trade-off insightful

There should be an efficient, systematic way to rate the criticality and use this to decide upon security requirements and the appropriate security assurance instruments. The aim is to make this trade-off between invested resources and degree of assurance insightful, as well as to help determine how critical a product is for the organization and the degree of assurance that should therefore be obtained.

We developed a methodology to obtain a quick but useful indication of the product criticality as well as the degree of assurance that is or should be in place. This indication will be used to help prioritize what products or vendors require further attention and on which aspects specifically. The methodology is implemented in an interactive tool, in which the user is required to answer a set of questions relating to the product, vendor and the assurance measures that are already in place. The challenge is to find an implementation that is insightful yet keeps the effort required by organizations to a bare minimum. The methodology will be tested and refined based on a set of representative use-cases within the financial institutions involved in the SRP.

In contrast to most projects in the SRP, which focus on problems in the near future, this is a challenge that currently exists, and can be addressed today. This also means that the outcome of this research can be verified and, ideally, be implemented in an operational setting when finalized.

Foundation of the methodology

There are many works available that target third-party security management. A wide variety of information is available; industry standards, guidelines, best practices and even tooling that deals with the subject. Most of the literature we analyzed, deals with topics from the perspective of doing things more accurately and thoroughly. In contrast, our aim has been to do things smarter and more efficient. The literature served as a great starting point for the structure to adopt in the tooling and as a way of coming up with the right questions to ask.

Among others, we adopted the third-party security management model as presented by Nokia (depicted in Figure 2) during the 'Third Party & Supply Chain Cyber Security Summit' conference (Frankfurt, 2018). This model does a good job at capturing the different phases of a third-party relationship. For our methodology, it served as an overview of the different phases in which security governance and assurance instruments can be used.

Although there is a variety of tools that deal with third-party security management, we have yet to find one that solves the problem that is addressed in this research. Relevant survey tools exist even specific to the topic of vendor management (e.g. Google Vendor Security Assessment Questionnaires)[1], but none seem to provide the desired capabilities (e.g. aggregation of results, dashboard overview, etc.) that fill the need of this project, which will be further outlined hereafter.

Designing a practical tool

The first version of the tool is implemented in an Excel workbook. The workbook consists of a dashboard overview (Figure 3) as well as sheets with multiple-choice questions to be answered by the user. The questions are divided into three sections: product characteristics, vendor characteristics and degree of assurance. The list of questions is provided in Figure 4. It is important to note that the questions and their answers are deemed specific to the financial institutions and that these will likely need to be different for other industries. The product and vendor characteristics sections can be seen as a bare-minimum risk assessment, where a higher outcome increases the overall product criticality estimate. The degree of assurance section consists of a set of questions to determine the assurance measures that are already in place, which may thereby compensate for the former two sections. In other words; scoring positively on the degree of assurance lowers the overall criticality score. This works intuitively, as the product criticality score is used to determine whether or not action should be taken; when a higher degree of assurance is already achieved, there is a lesser need for further action.

The Excel prototype served as a convenient tool to validate the set of questions and scoring mechanism used to determine a product criticality score.

The challenge is to find an implementation that is insightful yet keeps the effort required by organizations to a bare minimum.

[1] https://github.com/google/vsaq

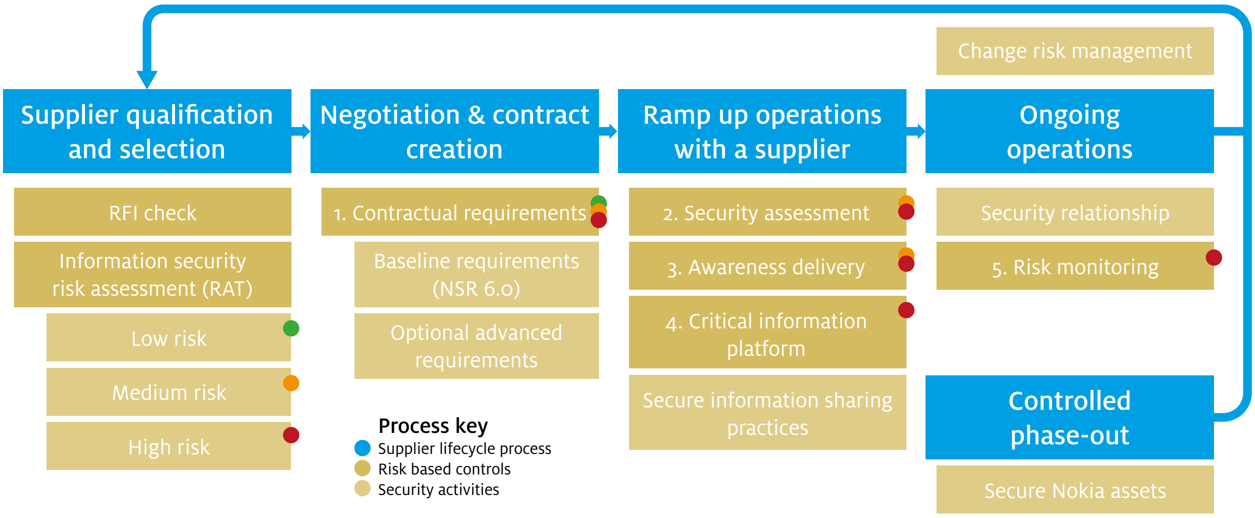
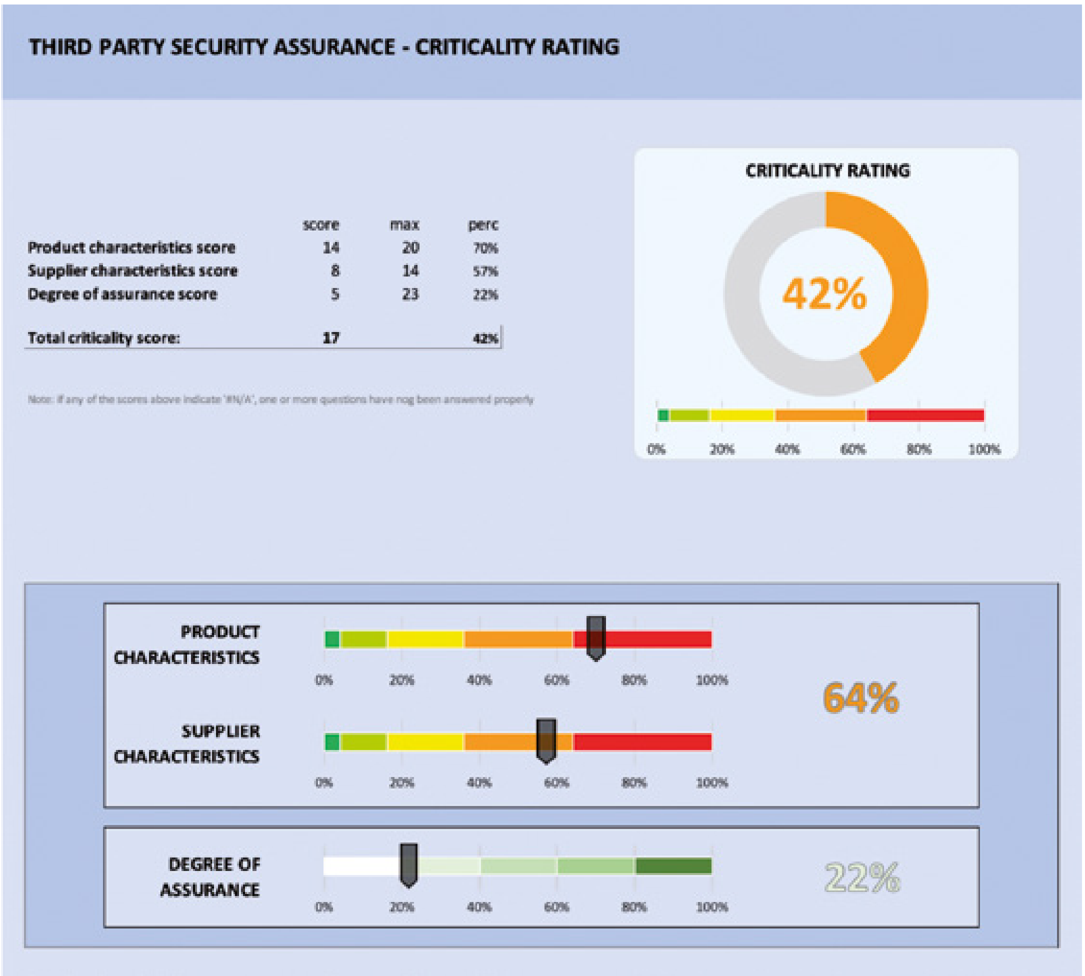

Supplier qualification and selection
RFI check
Information security risk assessment (RAT)
Low risk
Medium risk
High risk
Negotiation & contract creation
1. Contractual requirements
Baseline requirements (NSR 6.0)
Optional advanced requirements
Ramp up operations with a supplier
2. Security assessment
3. Awareness delivery
4. Critical information platform
Secure information sharing practices
Change risk management
Ongoing operations
Security relationship
5. Risk monitoring
Controlled phase-out
Secure Nokia assets
Process key
Supplier lifecycle process
Risk based controls
Security activities

Figure 2: Third-party security management model adapted from the model presented by Nokia during the Third Party & Supply Chain Cyber Security Summit (Frankfurt, 2018).

The validation showed that it was possible to quickly obtain a useful indication of the product criticality.

Both the list of questions and the scoring mechanism were improved over several iterations and were tested using a set of representative use-cases. The validation showed that it was possible to quickly obtain a useful indication of the product criticality. The use-cases that were examined first were that of actual products used in operation. These scored low in overall criticality, which is in line with expectations, as they and their vendor are either trusted or appropriate assurance measures have already been taken. To validate the tool for more extreme scenarios that were not present among the real-life cases, it was also tested using mock data that was considered representative for other more critical products and less-reputable companies. While official validation is yet to be done, the outcomes proved intuitive and the tool satisfyingly captured the extremes, thereby showing potential for actual implementation. The next step to more accurately determine the usefulness and applicability of the methodology is to conduct a systematic and more widespread evaluation, preferably carried out by actual end-users during operation.



THIRD PARTY SECURITY ASSURANCE - CRITICALITY RATING

	score	max	perc
Product characteristics score	14	20	70%
Supplier characteristics score	8	14	57%
Degree of assurance score	5	23	22%
Total criticality score:	17		42%

Note: If any of the scores above indicate '#N/A', one or more questions have nog been answered properly

Figure 3: Dashboard overview of the Excel tooldegree of assurance.

The second stage of this research, which is currently ongoing, focuses on a new, improved version of the tooling. The Excel tool, although useful, is rather inflexible and the use of a dedicated workbook for every product makes it difficult to analyze and compare results on a larger scale. The new version is designed as a dedicated web-based environment and is largely built from scratch. This new environment makes it more accessible for users while also greatly facilitating the addition of features and changing of existing functionality. Most importantly, this approach enables a dynamic, centralized environment that collects results in a single database, thereby providing a solid basis for creating aggregated views or summaries of the data.

This approach enables a dynamic, centralized environment that collects results in a single database, thereby providing a solid basis for creating aggregated views or summaries of the data.

Among the added functionalities are a dashboard overview with aggregated information, dynamic questions, form validation, a management summary and settings to control both the content and the framework (part of the functionalities are depicted in Figure 5). These functionalities are there to create an intuitive design, the prevention of errors and more valuable insights with less user efforts. The settings are there such that the tool can easily be tuned towards specific needs and to adapt to changing insights. The modular design of the framework itself makes it easy to add or change functionalities over time.

A. Product characteristics

A1. What is the nature of the product or service that is acquired (hereafter simply denoted as 'product')?

A2. Are the contractual conditions set by the own party or established by the supplier?

A3. What is the nature of the business process in which the product is employed?

A5. To what extend will the continuity of the business process rely on the product?

A6. What best describes the data that will be processed by the product?

B. Vendor characteristics

B1. Will the supplier gain autonomous access to internal infrastructure?

B2. Will the supplier get autonomous access to the data (as described in A6)?

B3. Are there reasons to question the supplier's competence or intent?

C. Degree of assurance

C1. Are there relevant certificates or TPAs in place?

C2. Do the available certificates or TPAs cover all security requirements?

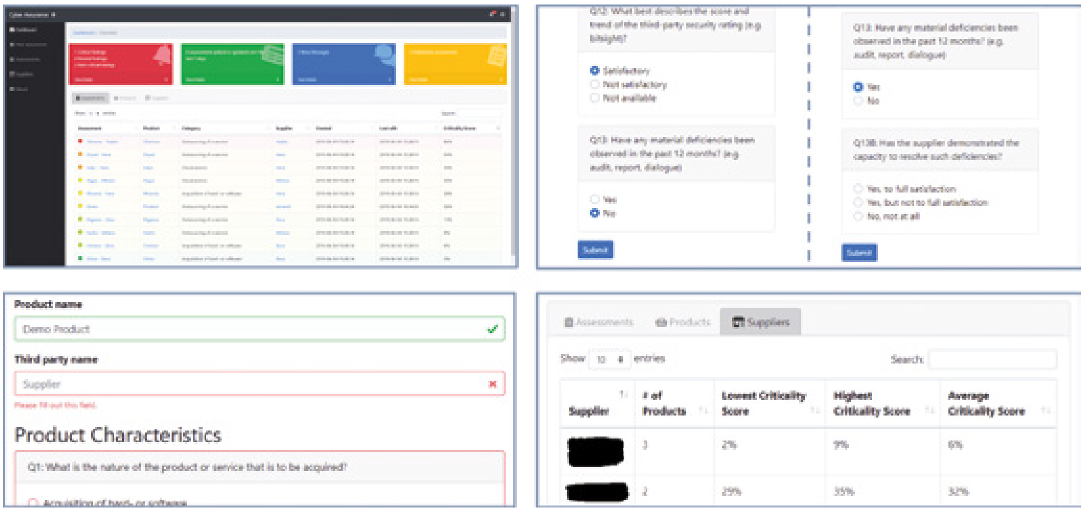
C3. Are there arrangements in place to address requirements not covered by certificate or TPA?

C4. What best describes the score and trend of the third-party security rating?

C5. Have any material deficiencies been observed in the past 12 months? (e.g. audit, report, dialogue)

Figure 4: Question list to assess the product criticality rating for financial institutions; product characteristics, vendor characteristics and degree of assurance

Gaining insight in the degree of assurance in relation to product and vendor criticality is a problem that transcends the financial domain.



Q12: What best describes the score and trend of the third-party security rating (e.g. bitsight)?

● Satisfactory
○ Not satisfactory
○ Not available

Q13: Have any material deficiencies been observed in the past 12 months? (e.g. audit, report, dialogue)

○ Yes
● No

Submit

Q13: Have any material deficiencies been observed in the past 12 months? (e.g. audit, report, dialogue)

● Yes
○ No

Q13B: Has the supplier demonstrated the capacity to resolve such deficiencies?

○ Yes, to full satisfaction
○ Yes, but not to full satisfaction
○ No, not at all

Submit

Product name

Demo Product ✓

Third party name

Supplier ✗

Please fill out this field.

Product Characteristics

Q1: What is the nature of the product or service that is to be acquired?

○ Acquisition of hard- or software

Show 10 entries
Search:

Supplier	# of Products	Lowest Criticality Score	Highest Criticality Score	Average Criticality Score
[redacted]	3	2%	9%	6%
[redacted]	2	29%	35%	32%

Figure 5: Overview of web-tool design. From left to right, top to bottom; dashboard overview, dynamic questions, form validation, aggregation of assessments

Conclusions and future work

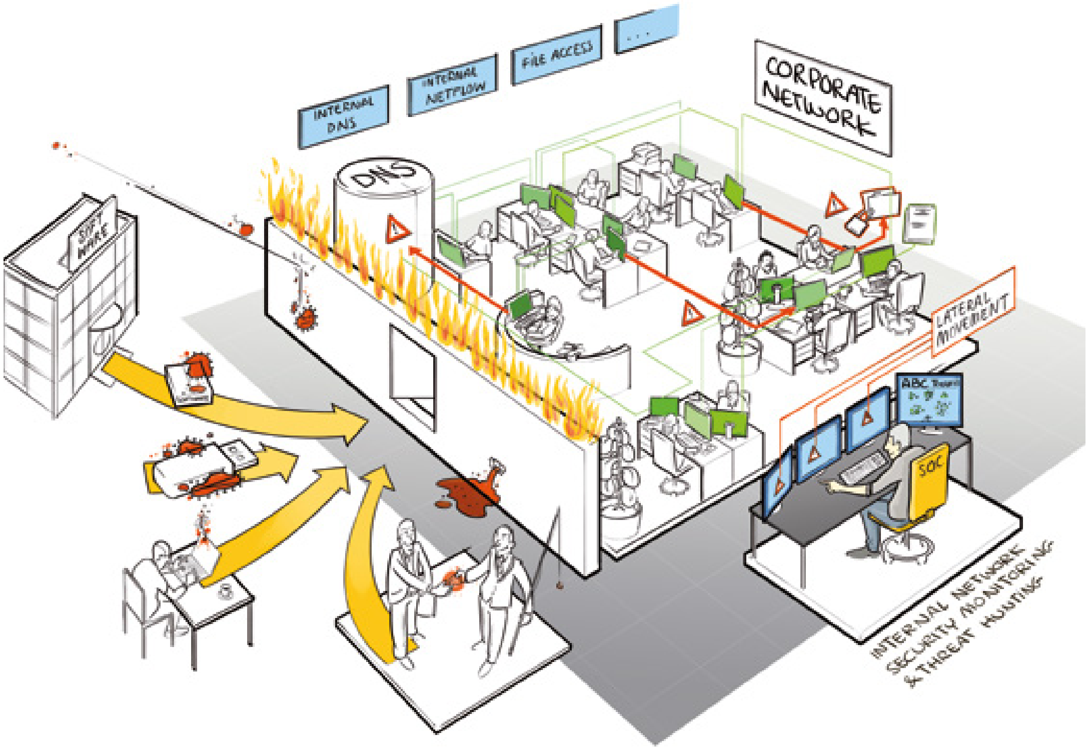
Third-party management is a challenging task due to the widespread dependencies and highly dynamic environment. Gaining insight in the degree of assurance to help determine whether or not further measures should be taken is a difficult and time-consuming process. To deal with the limited time and resources that are available, it is important to base assurance requirements and the amount of control on the criticality of a product and its vendor in relation to the business processes. The assurance measures and the importance to the business should thereby always be balanced. We designed a methodology to make this trade-off insightful and implemented this in a practical tool.

The final stage of this work will deal with end-user validation. This will be the final proof of the tool's operational usefulness as well as a possibility to further refine its functionality. When finalized, the tool may serve as a guideline for operational management in day-to-day use.

Gaining insight in the degree of assurance in relation to product and vendor criticality is a problem that transcends the financial domain. The general structure and method described in this article are applicable to any organization that deals with third-party management and may therefore be useful for a broader public. Future work may be done in order to gain insight in the potential differences that exist and assess what is required in order to bridge the gap.

Detecting Lateral Movement with Anomaly-Based Clustering

Alex Sangers (TNO), Erik Meeuwissen (TNO), Kadir Kalayci (Achmea)



We focus on finding anomalies (i.e. deviations from normal behavior) in internal network communication patterns which may be an indication of lateral movement in the cyber attack kill chain.

Introduction

Cyber attacks are getting more and more advanced and targeted. The traditional eggshell model of a hardened perimeter and a more or less open internal network is no longer sufficient (ClearSky 2018). In this research, we assume that a security breach already took place, and we investigated how it can be detected using internal network traffic (Beukema 2017). In fact, we focus on finding anomalies (i.e. deviations from normal behavior) in internal network communication patterns which may be an indication of lateral movement in the Cyber attack kill chain (Cutler 2010). To this end, the generic Anomaly-Based Clustering (ABC) toolkit has been developed.

It has the following key features:

- Applicable to data commonly available in IT environments (e.g. internal DNS, internal Netflow, file access logs). In fact, we use available data sources to model internal enterprise networks; we specifically focus on which end points (hosts) communicate with each other, and how much. The data does not need to be labeled with cyber attacks.
- Automatic clustering of hosts in the network with similar communication patterns.
- Statistical modeling of normal communication behavior between clusters.

- Detecting when individual end points start to deviate from the baseline of normal behavior. Typically, such deviations may indicate network misconfigurations as well as lateral movement as part of a Cyber attack.
- Internal network visualization and anomaly visualization to support SOC analysts and threat hunters.

The ABC toolkit supports anomaly detection and threat hunting [SQRRL 2018]. For example, by starting from a specific hypothesis of how a successful Cyber attack on an organization could take place, it can be used to search for such an attack. Thus, it can be considered as an extra line of defense to complement real-time detection based on signatures or blacklists.

The remainder of this paper is organized as follows. First, we describe the rationale behind Anomaly Based Clustering. Then, we describe the process steps supported by the ABC toolkit. Next, we describe the experimental validation with a real-life dataset consisting of file access logs. Finally, we end with conclusions.

Rationale behind clustering of hosts

One of the research challenges for anomaly detection in internal network communications traffic is to create a useful model of normal behaviour. As individual hosts typically behave relatively unpredictable, the ABC toolkit models groups of hosts (i.e. clusters) with similar communication behavior. This helps to reduce false positives caused by irregular behaviour of individual hosts. Moreover, it improves scalability such that large networks can be modelled (e.g. more than 100.000 end points).

Process steps supported by the ABC toolkit

When using the ABC toolkit, a threat hunting hypothesis must be developed. To effectively use the ABC toolkit, the hypothesis should consist of attack steps such as lateral movement or internal data exfiltration. The threat hunting scenario might also depend on the availability of data sources on the internal network. The attack (steps) should hypothetically impact available data. The ABC toolkit approach consists of the following six phases:

As individual hosts typically behave relatively unpredictable, the ABC toolkit models groups of hosts (i.e. clusters) with similar communication behavior.

1 Data selection.

Define a threat hunting scenario and find data where deviating communication patterns between source and destination addresses might indicate an attack. The data should consist of information on what systems communicating with what systems with what volume. Some examples of suitable data sources for threat hunting scenarios:

a. Based on Netflow data, e.g. port 1433 for detection of anomalous connections to SQL servers.
b. Based on file access data: detection of anomalous file path attempts.
c. Based on DNS data: detection of anomalous A-queries of hosts to the DNS resolver

2 Data parsing.

Filter, clean and process the input data to a format that can be interpreted by the subsequent modules of the ABC toolkit. Examples of filtering are IP addresses that are expected to behave anomalously by nature, and data that is irrelevant for the threat hunting scenario.

3 Clustering and network visualization.

The selected clustering technique is called Louvain clustering [Blondel 2008]. Louvain clustering is a community detection algorithm that groups hosts that are strongly interconnected between themselves in a cluster, and less strongly connected to other clusters. The clustering is automatically determined based on the communication patterns in the historical (network) data.

4 Clustering and cluster modelling.

The Louvain clustering ensures that hosts within a cluster are strongly interconnected. Traffic within a cluster is assumed to be normal. Traffic between clusters is considered to be interesting to monitor. Each cluster has so-called inter-cluster communication models that captures the normal traffic between that cluster and other clusters. The inter-cluster communication models are statistical models of communication between clusters based on training data.

5 Anomaly detection.

Compare the inter-cluster communication models with new (test) data to find deviating communication patterns between hosts in different clusters. A sudden increase of inter-cluster communication might indicate a host is deviating from its normal behaviour. The ABC toolkit detects three types of anomalies:

a. A host with a statistically significant increased amount of traffic to hosts in another cluster.

b. A host that communicates to hosts in another cluster, although no communication between the corresponding two clusters existed in the inter-cluster communication models.

c. A host communicates to hosts that were not present in the inter-cluster communication models at all.

The output of this module is a prioritized list of (anomalous) hosts.

6 Anomaly inspection.

Zoom into the behaviour of individual anomalous hosts. Both the inter-cluster communication model of the host and the communication during testing are visualized and can be compared. In addition to the visualization, a text file providing the corresponding data rows has been generated to support actionable follow-up.

The process steps are visualized in Figure 1.

Experimental validation for the use case file ac cess logs

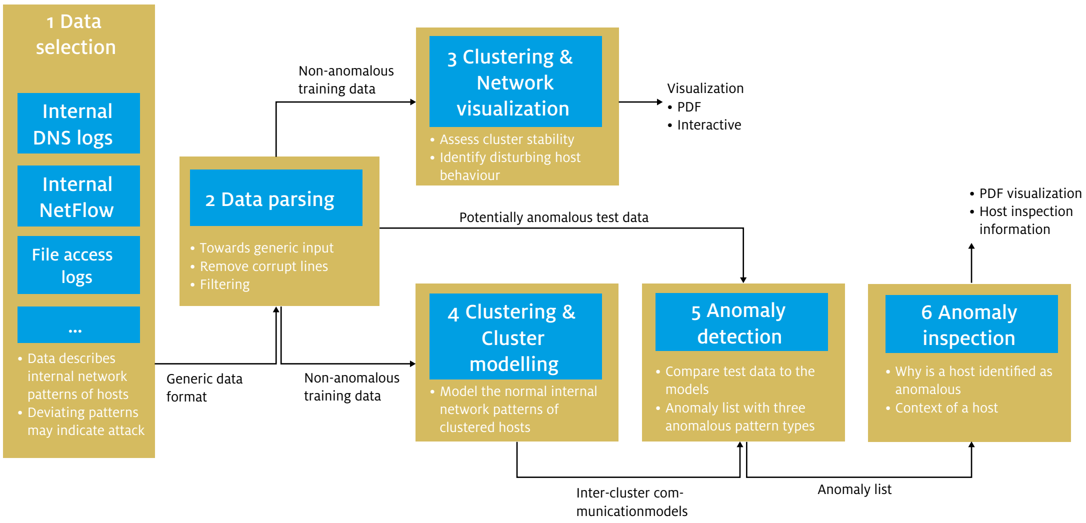
To apply the ABC toolkit to several use cases, it is important to understand the modelling and detection approach to determine what use case to develop. The use case should consist a threat hunting scenario including the available data source with (internal) source and destination addresses.

File access data consists of data on at what time what user was trying to access which file location. It is also includes whether the user was reading, writing or executing the file and whether this was a successful attempt or not. We executed an experiment with real-life file access data to identify hosts that had anomalous file access attempts.

1 Data selection.

We used file access data with user ID as source address and file path as destination address. The threat hunting hypothesis is that an adversary is already inside and scanning for commercially or privacy sensitive data that is stored on one or more file servers. Deviations in file access data indicate that a user is attempting to access file paths more often than usual or attempting to access other file paths than usual. This behaviour might be caused by a fraudulent employee or an adversary that is gathering data.

File access data consists of information on whether the user was reading, writing or executing the file and whether this was a successful attempt or not.



1 Data selection
Internal DNS logs
Internal NetFlow
File access logs
...
• Data describes internal network patterns of hosts
• Deviating patterns may indicate attack
Generic data format
2 Data parsing
• Towards generic input
• Remove corrupt lines
• Filtering
Non-anomalous training data
3 Clustering & Network visualization
• Assess cluster stability
• Identify disturbing host behaviour
Visualization
• PDF
• Interactive
Potentially anomalous test data
Non-anomalous training data
4 Clustering & Cluster modelling
• Model the normal internal network patterns of clustered hosts
5 Anomaly detection
• Compare test data to the models
• Anomaly list with three anomalous pattern types
6 Anomaly inspection
• Why is a host identified as anomalous
• Context of a host
• PDF visualization
• Host inspection information
Inter-cluster communicationmodels
Anomaly list

Figure 1: The process steps of the ABC tooling.

Many users only accessed a limited number of file paths and many file paths were accessed by only a limited number of users.

2 Data parsing.

The data was filtered on some anomalous systems that are anomalous due to their functionality, and corrupt data rows were removed. Additionally, the data was formatted to the generic format. The training data is based on file access data of the first half of a working day (12 hours) and the test data is based on the second half of that working day (12 hours).

3 Clustering and network visualization.

The community detection of the file access training data is shown in Figure 3. Each node in the graph represents a user or file path and each colour represents a community. Note that many separate small communities exist, meaning that many users only accessed limited number of file paths and that many file paths were accessed by only a limited number of users. In the middle of the graph a larger number of nodes are connected. There exist a small number of communities within this middle part. This indicates that there are users and file paths connecting all together, but some parts are more connected than others. In Figure 3, we recognize some similar patterns but there are some differences on first sight. Firstly, more nodes are present, indicating more users and/or file paths present in the second data set. Secondly, the middle part that is connected has more nodes but similar number of clusters that are identified.

For the sake of experimentation the clusters were deemed to be sufficiently similar based on visual inspection of these figures.

4 Clustering and cluster modelling.

The first half of the working day, shown in Figure 3, was used as training data to develop a baseline. The baseline consists of inter-cluster communication models that provide a statistical analysis on the communication of hosts between clusters.

5 Anomaly detection.

The inter-cluster communication models as developed in the previous step were compared to the test data as visualized in Figure 1. The result is a list of anomalous user IDs. The most anomalous host was assigned to cluster 683 and has a significantly increased number of file path visits, attempts to access file path that were not visited by its cluster during the training period and it also visits file paths that were not seen in the training period yet.

6 Anomaly inspection.

Zooming into the behaviour of the anomalous host shows what communication was anomalous. The anomalous host was assigned to cluster 683 and that cluster has had some communication to cluster 44 during the training period (Figure 4). During the testing period, the anomalous host in cluster 683 started visiting significantly more file paths belonging to cluster 44, started accessing file paths in cluster 700, which did not occur in training period, and started visiting new file paths that were not even present in training data, represented by cluster 701. This is shown in Figure 5.

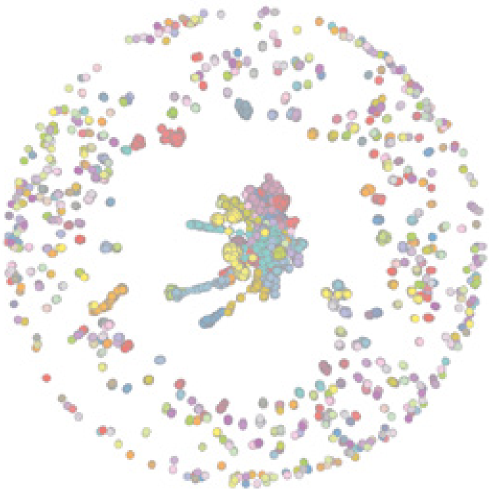


Figure 2: Cluster visualization of file access data of the first half of a working day.

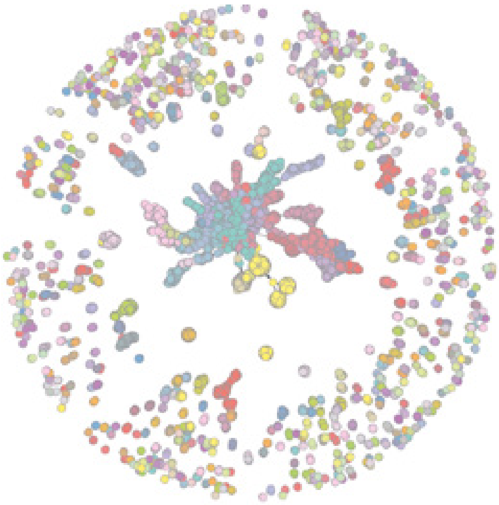


Figure 3: Cluster visualization of file access data of the second half of a working day.

In addition to the visualization, a text file providing the exact file access attempts has been generated to support actionable follow-up.

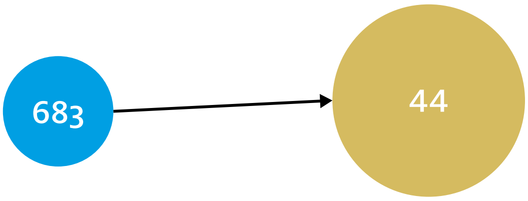


Figure 4: The communication behavior of the host in cluster 683 during the training period.

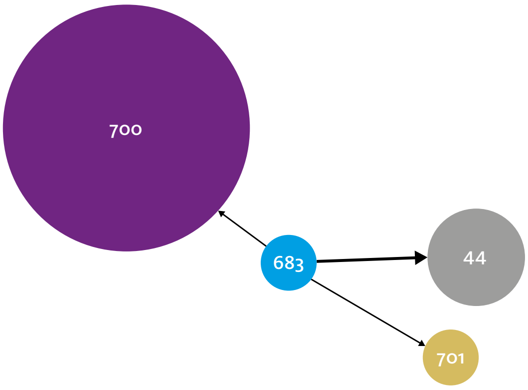


Figure 5: The communication behavior of the anomalous host in cluster 683 during the test period.

The output of the Anomaly Based Clustering approach was further investigated. It appeared that the user was rightly classified as anomalous, but that is was not related to an ongoing Cyber attack.

Conclusion

The ABC toolkit can be used as a threat hunting tool to inspect various internal network data sources (e.g. internal DNS, internal Netflow, and file access data) and is generically applicable lateral movement detection. The ABC toolkit has the following unique properties:

- **The ABC toolkit** has shown to be practically applicable on a real-life file access data set and rightly identifies anomalies.
- **No prior knowledge** about the IT network, infrastructure or systems is required. The toolkit automatically develops the baseline based on observed historical data. If this historical data is updated, internal network changes are automatically taken into account.
- The use of unsupervised machine learning does **not require labelled data** with known threats., The (Louvain) clustering enables to automatically model normal communication patterns. In contrast with other approaches which use signatures, the ABC toolkit can be used to detect newly developed attack steps due to anomaly detection.
- By modelling behaviour of clusters of hosts instead of modelling the unpredictable behaviour of individual hosts, the number of **false-positives** is **reduced**. In addition, the clustering offers a **scalable** solution for anomaly detection with tens of thousands of hosts. Moreover, the clustering is based on the communication within the whole internal network, so that the outcome is not predictable by attackers.
- The output of the ABC toolkit is **actionable**; it results in a prioritized list of anomalous hosts including what deviating communication patterns triggered the detector. Therefore, it is easy to follow-up on the anomalies by looking into the context and the content for further security investigation.

The (Louvain) clustering enables to automatically model normal communication patterns.

A next step is to practically evaluate the toolkit during red team activities to further improve its functionality and validate its effectiveness to detect lateral movement. The ABC toolkit has initially been developed for threat hunting; another next step is to extend the ABC toolkit to detect lateral movement (near) real-time.

The ABC toolkit is developed in collaboration with the SRP partners ABN AMRO, Achmea, ING and Rabobank. The experimental software is available “as is”. Parties who are interested to apply the ABC toolkit on their internal network data are invited to contact TNO.

Next step is to practically evaluate the toolkit during red team activities to further improve its functionality.

Bibliography

[Beukema 2017] Beukema, W.J.B., Attema, T., Schotanus, H.A. 2017. “Internal network monitor-.” Proceedings of the 3rd International Conference on Information Systems Security and Privacy. SciTePress. 694-703.

[Blondel 2008] Blondel, V.D., Guillaume, J., Lambiotte, R., Lefebvre, E. 2008. “Fast unfolding of communities in large networks.” Journal of Statistical Mechanics.

[ClearSky 2018] ClearSky. 2018. Cyber Intelligence Report 2017. Technical Report, ClearSkye Cyber Security Ltd.

[Cutler 2010] Cutler, T. 2010. Anatomy of an advanced persistent threat. Accessed May 2019. http://terrycutler.com/news/securityweek%20-%20anatomy-advanced-persistent-threat.pdf.

[SQRRL 2018] SQRRL. 2018. “A Framework for Cyber threat hunting.”

Colophon

© 2019 Participants in the Shared Research Program Cyber Security

Editors

Reinder Wolthuis and Richard Kerkdijk

Contributing experts

ABN AMRO: Brenda van het Hul, Christiaan de Groot, Ilona Scheerder, Jenny Gershkovich, Luc Verholt, Maarten Zwaan, Mark Kazemier, Mark Wiggerman, Martine Kea, Michael van den Berg, Olaf Streutker, René Sibbel, Ron Luttik, Sander Oerlemans, Shairesh Algoe, Steven Raspe, Ton Poppe

Achmea: Daniël Gorter, Fleur Bello, Kadir Kalayci, Marco Simmers, Mike Couwenbergh, Rob Faber, Robert Smit, Rogier Reemer, Tom Huitema

ING: Bob Bekker, Florian Schneider, Isik Yavuz, Leonie Schouwenaar, Mirna Bognar, Oscar Bloemen, Pieter Siedsma, Rene Scholte, Rianne Lieuwens, Ruud Zwan, Sander van de Kolk, Sander Zeijlemaker

Rabobank: Arnold Schekkerman, Bert van Ingen, Eric Kaasenbrood, Gauke Witteveen, Hein Laan, Henny van de Pavert, Jan Veldsink, Kees Hoogewoning, Leonie Schouwenaar, Marco van der Kraan, Paul Samwel, Walter Leemhuis

TNO: Alex Sangers, Anne-Marie Brouwer, Bart Gijsen, Daniël Worm, Erik Meeuwissen, Frank Fransen, Frank Phillipson, Frank Schuren, Gabriele Spini, Harm Schotanus, Hidde-Jan Jongsma, Hiddo Hut, Jeffrey Panneman, Maran van Heesch, Marie Beth van Egmond, Mark Buningh, Peter Langenkamp, Pieter Venemans, Piotr Zuraniewski, Reinder Wolthuis, Richard Kerkdijk, Robert Seepers, Thijs Veugen, Thomas Attema, Wieke Oldenhof, Wouter Langenkamp

Volksbank: Paul Gloudemans, Peter Rochat, Peter Wijkmans, Rob van Os, Ron Werther, Sijmen Veenstra

Illustrations: jamvisualthinking.com
Design: PI&Q grafisch ontwerp
Print: Zalsman BV

Copyright

Contact

reinder.wolthuis@tno.nl
wegwijzer@tno.nl

Types

#	●	Service	Port
1	●	http	80
2	●	domain	53
3	●	ms-term-services	3389
4	●	unknown	21320
5	●	microsoft-ds	445
6	●	snmp	161
7	●	ms-sql-s	1433
8	●	ssh	22