UNIVERSITY OF GOTHENBURG

A Structured Approach to Review and Refine Architecture Documentation

Bachelor of Science Thesis in the Software Engineering & Management Programme

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Department of Computer Science and Engineering
Göteborg, Sweden Mars 2016

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Abstract—**Over time a software architecture documentation can stray from the original path. In particular when the development is done in distributed self organizing teams. To refine an existing architecture to adapt to an evolved situation you need to answer what should be captured in the architecture and who knows what it should contain. In this study I suggest a process to first find what needs to be refined by comparing an architectural description against a scenario description. The output from that process is used to find what to capture in the refined design by interviews with developers. And finally the resulting design is validated against a group of stakeholders. This process shows an impact both on the architecture and on aspects of the organization.**

I. INTRODUCTION

When systems are developed the design can take a different path from the intentions reflected in the architectural documentation. With time, growing complexity, and if development is geographically distributed, there is a risk that a team no longer can anticipate how their contribution fits with the overall system and what has already been implemented elsewhere. When this occurs in organizations using agile methods, how is it possible to find a way back to a common well defined architecture?

Another question is what the architecture should capture? And who knows what it should contain? There are numerous ways to evaluate a software architecture in relation to quality attributes [1]. The same is true when reviewing the *architectural documentation* (AD) to see if it has the desired quality attributes [2], [3]. These approaches allow and encourage the use of scenarios to perform the evaluation.

In traditional, non agile, organizations there is a notion of the importance of software architecture (SA) as a tool to structure and reason about the systems [4]. In Agile environments there has been resistance to the SA [5]. But architecture centric approaches can be tailored to fit in an agile environment [6]. Still there is a lack in the understanding of how SA artifacts should be used in agile contexts [7]. Martini et al. defines three roles for architects in an agile environment, chief architect, governance architect, and team architect. Common for all the roles is the need to spread architectural knowledge through the organization. Though some of the traditional architects tasks gets transferred to individual team members [8].

A process suggested in "A Structured Approach for Reviewing Architecture Documentation" (SARAD for short) [9] aims to structure a review of an architectural documentation by letting stakeholders review it through a set of predefined questions.

However, having a clear picture of the gap between the architectural documentation and the emergent design does not necessarily help the developers to make informed decisions on what to do next – for this to be possible the gap has to be closed.

This leads to the research questions:

- RQ1: How can an architectural documentation be evaluated against a scenario description using SARAD?
- RQ2: How can SARAD be enhanced to align the architectural description and the scenario?
- RQ3: What are the pros and cons using the enhanced SARAD in RQ2 compared to the evaluation in RQ1?

I investigated how to review and refine the architectural documentation so that the developers can decide and prioritize their next steps in the development process. The contribution is a three-step process.

In this project SARAD is applied by what can be described as "asking the questions to the documents" to evaluate an AD against a scenario description. The questions are based on a framework for analyzing information systems presented by Shannon in 1948 where information have a source, is sent by a transmitter over a channel and received by a receiver at the destination [10], [11].

The output of that step is then used to not only find which qualities are missing but also to show how missing qualities can be accommodated in the design through interviews with the developers.

As the third step the new suggested architecture is validated through a stakeholder workshop.

By collecting and spreading architectural knowledge through the distributed agile team, this design process refines the way such teams can work with architecture. It also refines the roles from Martini et al. [8].

This report has the following sections: "Background" outlines the studied system. It also describes SARAD in more detail and puts the study in a larger research context by a related works section. "Research strategy" is a four part

section where the first section explains how the study was structured around the action research framework. Second is a section on how SARAD was applied to the case in order to answer RQ1. In the third part, an extension of the method based on interviews is applied to help answer RQ2. Both these parts respectively contains data collection, data analysis, verification and validity of results. The fourth part gives an overview of the combination of results from the two previous parts. "Results" is an in depth view of the results from the study with subsections each answering one of the three RQ:s. "Discussion" contains the interpretations of the results. "Conclusions & future work" summarizes the main aspects of the report and suggests next steps for future research.

II. BACKGROUND

This section provides context to the study. First is the organizational context. Second are descriptions of the simulator lab and the two central documents, the Demo-case description (DD) and the simulators architectural description (SimAD). The third part outlines the SARAD approach by Nord et al. [9]. The last part "related work" places this study in a context within its scientific field.

A. Organization

Second road phase 2 is a Vinnova financed joint research project spanning several organizations. Viktoria ICT, VCC (Volvo car corporation), Semcon and VTI (The Swedish national road and transport research institute) are among the participants. The projects goal is to shorten the development time in the automotive industry by e.g. the use of simulation techniques [12] and open for the development of advanced features such as cloud connected and autonomous vehicles [13].

Viktoria ICT is responsible for managing Sub project 5 (SP5) of Second Road phase 2 and the development of a real time simulator lab.

The development process model in SP5 is a loosely defined agile method. The team is distributed over the previously mentioned organizations and synchronized through weekly work meetings and monthly development workshops.

B. The Simulator Lab

The purpose of the lab is to provide a development platform for new automotive features and be available for third party developers. The features can be represented by a model running on simulation hardware, software running on prototype hardware, or software running on target hardware. Relevant parts of the vehicle and its environment are represented by models running on simulation hardware [13].

1) The Architectural description: The simulators architectural description (SimAD) is based on a template for software architectural documentation according to ANSI/IEEE 1471-2000 [13], [14]. Different stakeholders were identified by a pre-study to the project with the goal of prioritizing quality attributes (QA).

Maintainability and modularity were central QA:s put forward by the stakeholders. Functional stability, compatibility
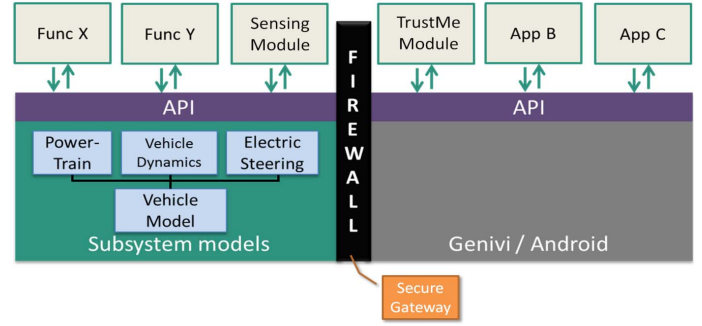

Fig. 1. A logical view of the vehicle part of the system with the secure gateway (firewall) in relation to the infotainment module. [13]

and security are other QA:s rated high. Those QA:s has formed the basic architectural decisions of the simulator lab and its base patterns.

The stakeholders intended as readers of the SimAD are the developers of the simulator.

The architectural patterns are based on the SimArch vehicle simulator reference architecture [15]. The adaptation of SimArch is done through four major modules:

a) The environment simulator: This is the module simulating the environment surrounding the vehicle. It is realized by an instance of the ViP simulator from VTI [16]. The visualization of the environment is handled by the Visir graphics engine [17].

b) The vehicle simulator: This is the module simulating the behavior of the vehicle in terms of vehicle dynamics, engine, control, safety systems and various other ECU:s. It uses proprietary SPA modules provided by VCC to simulate the behavior of a current XC90.

The vehicle part of the simulator is divided into two sections, one handling safety critical aspects of the vehicle and one handling non safety critical tasks such as the infotainment system. Controlling communication between the two parts is the secure gateway as visualized in Fig. 1.

c) Secure gateway: Is an implementation of a MQTT [18] broker with added layers of security. Its role is to negotiate a secure contact between the two parts of the system. MQTT implements a publish – subscribe pattern and provides means to control the signals passing to and from the connected units.

d) The infotainment unit: An Android device running the AGA (Automotive Grade Android) distribution of the Android OS [19]. The specifics of AGA compared to standard Android is that it provides an API to vehicle signals.

2) Physical deployment: The realization of the simulator is displayed in Fig. 2. The different parts are described below and referenced by the numbers in the image.

a) Environment simulator: The environment simulator is deployed on a HP workstation (5). The Visir output is through HDMI to a 55" screen (1) in front of the drivers seat.

b) Vehicle simulator: The vehicle simulator is executed on a dSpace Scalexio real time platform (3). Closely coupled with it is a steering wheel, pedals and a set of buttons and the driver information module (DIM) (5). The DIM is a dashboard

Fig. 2. Main simulator screen (1). Infotainment touch screen (2). dSpace Scalexio (3). Odroid Secure gateway & network router (4). Driver seat, pedals, steering wheel (5). Within the black enclosure at (5) is the HP workstation.

Fig. 3. A conceptual image from the DD of how the final visualization of TrustMe could look like [20].

from a XC90 connected to the vehicle simulator by Flex ray. The vehicle simulator and the environment simulator are connected by Ethernet.

c) Secure gateway: The unit is executed on a Beaglebone black (4) and connected to the secure side via CAN-bus and to the infotainment side through Ethernet.

d) Infotainment unit: This unit is executed on an Odroid C1+ (4). The output is on a 9" touch screen (2) placed by the drivers seat.

3) The TrustMe scenario: To aid in the development of the simulator and to create demonstrable results the project has agreed on three architectural scenarios gathered in the Demo-case specification document (DD) [20]. One aspect of the scenarios is to capture a wide array of functionality that needs to be implemented in the simulator. This study targets the TrustMe scenario.

The narrative introduction to the TrustMe scenario puts the reader in the situation where it supposed to be used:

> Imagine sitting idly behind the steering wheel of a self-driving car traveling at 90 km/h. Up ahead there is a bus about to cross the road. Within 5 seconds there will be a collision if no action is taken; you see the potential risk, but how do you know that the car does, and how do you know what plans the car may have to avoid an accident? TrustMe aims to provide a visualization of what the vehicle is aware of and plans to do — a window into the mind of the vehicle.[20]

So how should this be achieved? The idea in the DD is to use the display on the vehicles infotainment unit to show a moving image from a front facing camera. Overlayed that image are visual representations of what the vehicles sensors and refinement algorithms percepts of its surroundings and what the vehicle intends to do based on those perceptions. This is exemplified by Fig. 3 [20].
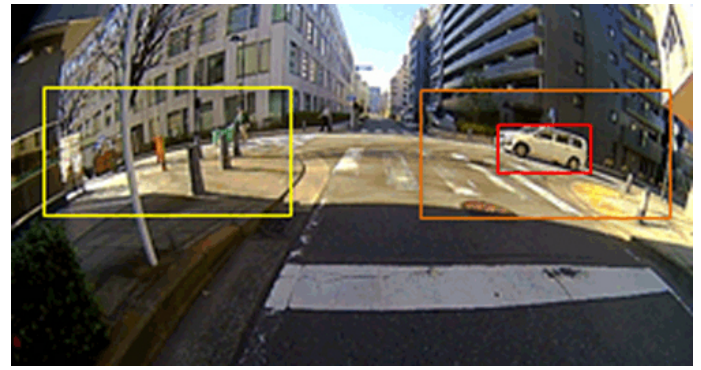
The DD assumes two high level modules in the simulator: One is percepting the vehicles surroundings and one is displaying an analysis of it. There is also assumed a physical driver interface with steering wheel, pedals and break as well as a large display showing the simulated environment as through a windshield. From this general scenario four sub-scenarios are derived:

1) Test the effectiveness of different visualization techniques and measure when the driver intervenes with the car.
2) Explore TrustMe as a driver support system when autonomous driving is disengaged. Here TrustMe should warn the driver and even engage active safety features in dangerous situations.
3) Explore different methods to facilitate the transfer of control between the autonomous vehicle and the driver.
4) The static scenarios. In contrast to the first three, that allow the driver to interact, the static scenarios only work with pre-recorded data. They are intended for quick demonstrations and to explore different types of visualization.

C. A structured approach for reviewing architectural documentation

In "A structured Approach for reviewing architectural documentation"[9] (SARAD for short in this report) Nord et al. proposes an approach to review an architectural documentation (AD) in order to determine if it is fit for a particular stakeholders concern. That concern could for example be to use the AD as a guide to develop the design, to do an ATAM evaluation of the design or to investigate if the AD adheres to a specific standard.

Nord et al. state that it is not yet a complete method since that "would come with a fully worked-out process model and a rich pedigree of usage" [9]. They argue that their approach is a valid starting point for a method since its conceptual heart "is rooted in wellgrounded practical methods with a long history of successful use" [9].

This approach emphasizes the difference between the architecture and the architectural documentation and that this is not
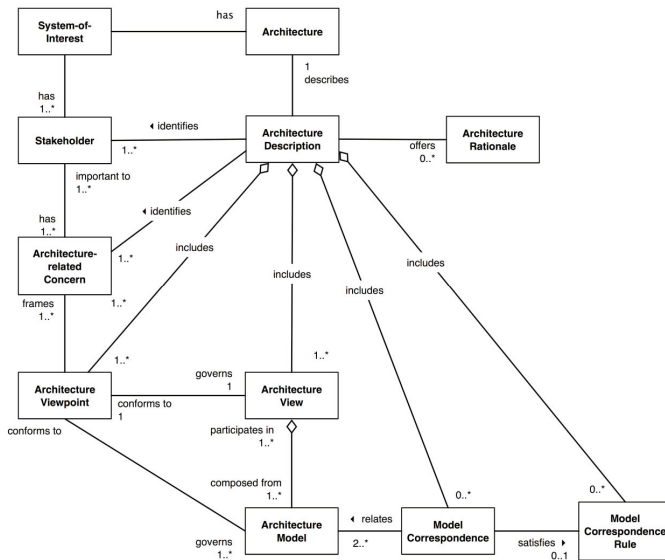
Fig. 4. The relations of an AD to the architecture, the system and the views. [9]

an evaluation of the architecture itself [21]. They refer to the distinction as outlined by ISO/IEC 42010:2007 which is an adaptation of ANSI/IEEE 1471-2000 [9], the same standard used by the SimAD.

They define the AD as a concrete artifact that documents the architecture of a system. An AD consists of several parts such as an identification of the stakeholders for the architecture and the system, an identification of the concerns of those stakeholders, a set of architectural viewpoints, a set of architectural views, exactly one for each viewpoint, architecture rationale to record key decisions [9]. This is illustrated by Fig. 4. A scenario is "a short statement describing an interaction of one of the stakeholders with the system" [1].

SARAD consists of six steps

1) Establish the purpose of the review
2) Decide what artifacts should be included
3) Build or adapt the appropriate question set
4) Plan the details of the review
5) Data collection
6) Data analysis

1) Purpose of the review: To know the purpose of what the AD should be reviewed for is a prerequisite to perform it. And that purpose has to be determined by the intended users of the AD [9]. Nord et al. argues that different stakeholders look for different aspects of the AD. The customer, the business manager and the implementer are not likely to be interested in the same properties of the AD [9]. According to Nord et al. the stakeholders involved in the activity for which the document is reviewed should be represented in the review team.

2) Artifacts of the review: In the examples from Nord et al. the artifacts used in the review situation is determined by the purpose of the review and decided by the designers of the review. Those artifacts can for example be standards

documents, process descriptions or tools used for the review. The only requirement is that the AD must be included.

3) Build the question sets: This is a central part of SARAD and determining much of the results of the review. The suggestion from Nord et al. is to create question sets for the purpose of a review that should be reusable.

4) Planning of the review: When the review is performed during the life cycle of the documents is loosely defined by Nord et al. It could either be used "proactively to provide guidance on what to document as a portion of each design/documentation step as well as be used as a separate review activity after much of the documentation has been completed." [9]. This step should also include decisions on how much time is spent on the review and the selection of participants.

5) Perform the review (Data collection): The review is performed by posing the questions to the stakeholders and gathering the answers. The form of the review is very permissive. It could be a face-to-face meeting or using many different channels of communication such as e-mail, wikis or messaging [9].

6) Analyze and summarize the results: The analysis of the data from SARAD is not required to use any particular method. One of the example cases involves a number of interviews resulting in numerous different answers. The intention with this step is to "aggregate the answers to the questions and then make a qualitative determination of the overall impact of the AD against the stakeholders and concerns" [9]. The result of that analysis is expected to be a nuanced conclusion of the findings in relation to the purpose of the review.

D. Related work

In a review of current practices for reviewing AD:s Barcelos & Travassos [3] point to that from "20 identified evaluation methods, 11 use questioning techniques to evaluate software *architectural documents*. The most common questioning technique among them is scenario based execution." One reason behind that is that several of the methods is based on SAAM (Software Architecture Analysis Method) [22]. They also point to advantages in using structured methods for evaluating architecture documents compared to ad hoc methods [3]. Their results suggest that reuse and generality are important qualities of the evaluation process and that it is preferred to evaluate the documented architecture instead of the implemented [3].

In contrast Babar et al. does a comparative review of scenario based evaluation methods of *architectures* [2]. They suggest a generic approach to the evaluation steps, but no clear definition of what is included in those evaluations since "all of the methods leave a SA undefined under the assumption that everyone knows what SA means" [2].

In a retrospect of 50 SA evaluations in industry Knodel & Naab aims to complement what they perceive as an overweight of theoretical papers in the field of SA evaluations with empirical data [23], [24]. Their purpose is to share their lessons learned and show that reviews of architectures can mitigate risks while introducing changes to software development projects [23]. They also found that in all of those 50

cases the AD "typically does not cover enough or the right type of information to explain how architectural requirements are supposed to be addressed" [24].

From the concern of the resistance to SA in agile environments, a case study by Babar [5] aims to explore which architectural practices are used by agile teams. He concludes that agile and traditional teams use similar architectural practices but in different ways. For example it is more common in agile settings to include the development teams in the process.

III. RESEARCH STRATEGY

This section first discusses the rationale for the use of action research (AR) as the overall research method. It also clarifies the details of the specific AR framework used. The next sections describe the process of how AR was applied in this specific case.

The AR process is done in two distinctive steps. First is the application of SARAD comparing the TrustMe scenario from the Demo-case description (DD) [20] to the Simulators architectural documentation (SimAD) [13]. Second is the design of an enhancement of the SimAD to verify the results of the first step and to extend the method. Both steps have been accompanied with information gathering on aspects of the system through openly available sources such as published articles and online documentation.

A. Research methodology

This study contains aspects that could motivate why it should be considered to be within more than one of methodological framework.

It is a study of a "contemporary phenomena, which are hard to study in isolation" [25]. By "phenomena" I consider both the process of development and the use and refinement of SARAD in an applied context. One important aspect is that in this case the researcher has been an important participant in both of the phenomenons and not just an embedded observer. According to Runesson & Höst "a case study is purely observational while action research is focused on and involved in the change process"[25]. They classify involvement of the researcher in the researched phenomenon a threat to validity in a case study. Robson [26] and Yin [27] on the other hand considers the participation of the researcher to be a possible part of a case study, classifying the researcher as a "participant observer". Since Runesson & Höst has adapted the case study framework specifically to the SE field it is more suitable to adapt their classification in this study. And by that, this study is outside the boundaries of a case study.

Design science research is another methodology in IS and SE research. The most important result of a design science research study is a design artifact [28]. And one central part of this study has been the design of a refined architecture. Aspects of the design science frameworks put forth of Hevner [28] and [29] has guided how the design of that architecture has been structured. This is reflected in the design being done in iterative steps, the design was verified to solve a defined business problem, and the design was thoroughly

communicated when it was finished. This is described in more detail in the section "A design extension". Though the design is a part of the study, the architects role and the way of working, not the design is the main contribution of the study.

Coming back to the classifications used by Runesson & Höst: A case study is purely participatory. And when the case study moves to the domains of action research when the researcher participates and is involved in the change process.

Action research is a method stemming from Kurt Lewins theories in the mid 1900's [30]. It has since been adapted to research in the IS field by for example McKay & Marschall [31].

The original rationale for using action research resulted from the researchers interest in learning about practices in its natural context through collective self-reflective inquiry. The goals was to improve practice and to obtain new knowledge [32].

McKay & Marschall identifies collaboration between researcher and "the problem owner" as essential to the success of the AR process [31]. In this case the collaboration has been close and open, as described in detail in a following section.

Another required feature of AR is the active and deliberate self-involvement of the researcher in the context of the investigation [31]. This is fulfilled by me as the researcher both are the one trying to solve the business problem as well as the research problem.

In the framework of McKay & Marschall the researcher plans a research project with the expressed purpose of finding answers to research questions. Action is taken while the researcher keeps the theoretical perspective in mind. The actions are evaluated considering the research interests, and evaluated for their effect in terms of the research questions [31].

To counter the risk of AR turning into consultancy McKay & Marschall positions the framework around two cycles, the problem cycle and the research cycle [31]. This is illustrated by the following quote: "This means that the action researcher has dual aims: the researcher must aim to bring about improvements through making changes in a problematic situation, and must also aim to generate new knowledge and new insights as a result of his/her activities".[31]

In this context the problem solving cycle is to solve the problem with the lack of architectural clarity for the start of implementation in the open innovation lab. The research cycle is regarding the actual process used to solve the problem and the possibilities to generalize from that process.

The iterative nature of AR has been somewhat locked in this project. McKay & Marschall states that if the research questions can be answered after any cycle in the research process, the researcher should then exit the context. If the RQ cannot be answered another research cycle is to be started until the RQ can get a satisfactory answer. In this project the problem solving cycle went through several iterations, as explained in detail in the following subsections.

To provide a complete process as an answer to the RQ:s required the business problem to be solved satisfactory to

the problem owner. Therefore both the problem solving and the research cycle had many small iterations leading up to a complete solution and a satisfactory answer to the RQ:s.

The answer to the RQ is perceived through the reflection on the action, the theoretical framework and the problem.

Therefore I consider this study as AR within the framework outlined by McKay & Marschall [31].

This study analyzes a single case where the skill of a number of stakeholders are important for the result of the process. By that the external validity is at risk of being low.

To be able to generalize from this study the context plays an important role. In the Omnibus approach of presenting research suggested [33] and [34] the researcher describes the "who, what, when, where and why" of the context.

Dybå states that the SE field contains a broad range of tasks and systems. We cannot claim a solution to be generally good or bad since the contextual parameters vary between workplaces and countries [34].

What is more useful for the reader of a report is a clear description of *what* was good or bad for *whom* performing *those* tasks under a certain set of *circumstances* [34]. This report is structured to supply that set of contextual information to the reader stating what worked or not under this set of circumstances. At the same time avoiding claims of general good or bad.

The research cycle is described in this report by the steps of research questions leading to the data collection, the data analysis and the results. Since Mckay & Marschall considers the processes of problem solving and research to be intertwined, in this report they are also reported intertwined and not separate to not remove focus from the nature of the two cycle AR approach.

B. Applying SARAD

The following sections are in detail how SARAD was applied following the six steps defined by Nord et al. [9].

1) Purpose of the review: The motivation for this step was the preconception from the team that qualities required to realize the scenario were missing in the SimAD and that there was no ground to start implementing the modules. Put differently they wanted to know if a developer could start implementing a first iteration of their part of the system according to the architectural description.

As defined by the SimAD the implementer stakeholders are the initial simulator developers (VCC, VTI, Semcon and Viktoria) and they are also the intended readers of the SimAD [13].

The viewpoint of the review is the one of the implementers. When the review process started they were approximately six months away from the planned start of the scenario implementation.

The expected outcome of the review was either an "all clear" to start implementing or an analysis that could be used as a basis for a design that would allow implementation. Nord et al. argues that identifying the purpose will identify the stakeholder. In this case it was in the reverse order. The
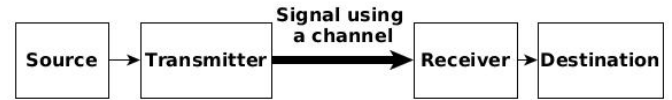

Fig. 5. Basic diagram of an adaptation of Shannons theory [10].

stakeholders identified a purpose of the review. The result was the required: both the stakeholders and the purpose were clear and aligned.

Since this method is applied by comparing documents, the requirement of stakeholder representation in the review process is fulfilled by using the DD as the comparison to the SimAD. Nord et al. states that the review meetings does not need to take place face to face but can be performed by exchanging documents for example over systems "such as wikis" [9]. All the groups of the developer stakeholders are presented as authors in the DD [20].

2) Artifacts of the review: In SP5 the aim of the architectural description is to be a stand alone and self explanatory artifact. Considering that intention no other artifacts but the entire SimAD will be included in the review. The SimAD refers to a set of other documents and the knowledge presented in them are also accounted for. The content of those documents are mainly general SA and simulator related books and providing rationale for the architectural decisions rather than details of the system.

3) Build the question set: To aim for reusability the questions are based on Shannons mathematical theory of communication systems that has been in use for over 65 years [10], [11]. For the purpose of the question set Shannons pair of terms (See Fig. 5) source/transmitter and receiver/destination has been simplified. In this study the term source also includes the transmitter and the term destination also includes the receiver. Since the abstraction of the studied system is high, I assume all channels to be noiseless.

The question set was then constructed in the following way: For each module required by the DD, is it described in the SimAD? Is the module a source and/or destination for a signal according to the DD? Is that signal defined in the SimAD? Is the channel of the signal defined in the SimAD? Is the destination of the signal defined in the SimAD? If an entity exists in the DD, can its source/channel/destination be found?

The modules and signals were extracted from both explicit descriptions of the systems (diagrams and text descriptions where the module and signal was named) or through implicit descriptions of functionality that was not connected to a named module or signal. The question set was constructed iteratively and the same part of the document revisited with a new iteration of the question set. The final data collection is based on a comparison of the entire documents using the final question set.

4) Planning of the review: In this case the project is using an agile method and the documentation is expected to be evolving. The used documentation is in a semi mature but

not final stage, 0.95 is the version number set by the authors.

Though the document is in a late version the intention rather fits the description of a proactive use to determine what needs to be documented.

The time in the life-cycle of the system was given by the need expressed by the team. The time set for the actual review, including data analysis, was originally 80 hours. The actual time required was less, about 60 hours. That time also includes the development of the question set.

5) Perform the review (Data collection): The review was performed by me reading the SimAD and taking notes of possible answers to questions in the question set one by one. Some did not have clear answers and some of them provided multiple answers. This was recorded in a note together with the answer. The reading required some iterations since there were a number of questions whose answer could be found in many places in the SimAD.

The general collection procedure was structured by suggestions on archival data collection by Runesson & Höst [25].

6) Analyze and summarize the results: The aim of the analysis was generation of theory [35] about what qualities were missing in the SimAD. During collection the data was labeled as either source, destination or signal according to Shannon [10]. The data were tabulated and color coded in a spreadsheet to visualize the answers [25]. The data were put in the same table as data on modules in the current implementation of the simulator. The data on the implementation was provided by the team members through informal interviews. The final analysis of the data was done by designing logical views and deployment views of first the DD, then the SimAD with differences marked visually, and finally the implemented simulator with the differences highlighted.

7) Verification: To apply SARAD in this manner is untested. And the review is done by me alone applying it to the documents. It would have made a stronger case if the same result was provided by more than one researcher. This is mitigated by multiple other strategies. The correctness of the resulting artifact is verified by the design study using interviews that covers all the developer groups responsible for the implementation of the simulator and with at least one representative for each module.

I have based the development of the critical question set on a well established theory that has been in use for the last 65 years [10], [11]. The data collection and analysis of the review was done according to established guidelines in the SE research field [25], [35]. The subsequent interviews and the development of an enhancement of the design based on the SARAD results are also factors supporting that they are valid.

C. A design extension

The second part of the study was done with the purpose of extending the SARAD evaluation. The interviews aim to both validate the results and to gather information on how to complete the SimAD to find and accommodate the missing qualities outlined by the SARAD evaluation.

1) Data collection: Data was collection by several methods: Semi-structured interviews, structured e-mail interviews, participant observation at formal meetings with the team, informal meetings (by the desk, in the hallways, over lunch etc) that occurred naturally by me working co-located with the team and by two workshops, one with two participants present validating a subset of the design, and one presenting all results to the complete project group. The main information source are the interviews, formal and informal. Field notes were taken [35] in all the data collection except the formal interviews that provided answers written by the interviewee. Before the interviews I signed a NDA to allow the participants to leave more open answers [36].

The interviewed roles were: i) SP5 architect and project manager, ii) Environment simulator developer from VTI, iii) Secure gateway developer from Semcon, iv) AGA developer from Viktoria ICT, v) Vehicle simulator developer from VCC. The interviews had a similar basic structure but there are also some differences.

Four of the interviews were semi structured where I had a clear set of questions but the answers were allowed to follow the needed direction. The intentions of the interviews were both to verify the current iteration of the artifacts and to gain new data for the next iteration of development. The questions were largely drawn from the missing qualities shown by the evaluation. They followed a structure of "Qualities A and B seems to be missing. Do you have an opinion on where to implement them". The semi structured approach provided openness in the answers [35] from which knowledge for further development was gained.

The verification questions were asked by presenting the evaluation and the current iteration of the the design and giving the interviewee the option to freely comment on it.

Since the interviewees together represented the implementors as a group but each had domain specific knowledge, a subset of the questions was targeted towards the interviewees domain.

The interviews with the representative of VTI and Semcon were preceded by sending them the questions with an opportunity to give a written answer. The representative from Viktoria ICT responsible for the overall architecture was provided with the SARAD evaluation prior to the interview.

The interview with the VCC representative was an e-mail correspondence. All the other interviews were conducted at the workplace of each person.

The informal interviews lasted an hour each. The interviews with the Victoria representatives, the VTI representative and the Semcon representative were also followed by informal meetings.

All implementors participating in SP5 were present at a validation workshop at November 3. They were presented the results from SARAD and the enhanced architecture. The group expressed their preference for one design variation for the image stream. Also some risks in the design were highlighted. Both those aspects are included in the final design. The results from SARAD were displayed but required no adjustments.

The Semcon representative was given a demo/workshop of a proof-of-concept of the proposed architectural solution for the video streaming on Nov 2.

During the course of the project I was participating as observer in a number of meetings with SP5. Those were both sprint planning meetings and work meetings. I also participated at a demo session within the scope of the entire Second road phase 2. All formal meetings lasted about 1-2 hours each at eight occasions from late September to late November 2015.

Those meetings gave a context to the project and its current state. It provided information to help clarify aspects of the project that was not documented.

The data collection was done in short sprints. Each sprint consisted of data collection and validation of the current iteration of the artifacts. The iterative process adapts to the idea of architecting as an iterative process as described by Bass et al. [4].

2) Data analysis: The data from the interviews has been analyzed with different goals: i) To validate the design and the SARAD evaluation and ii) to generate theory on how the enhanced design can be realized.

The approach for the first goal is based on the constant comparison method [35]. Coding of data can be done in many ways [35] in this case it consisted of updating the design using the notes from each interview. The generated data from the interviews has been put in relation to and complemented with patterns and solutions used in applications similar to the simulator lab.

The update of the design between each iteration has consisted both of a new design diagram and a new description of the system. This has sometimes resulted in multiple design options that has been presented during the next interview.

The validation of the previous iterations of the design and the SARAD result was done from the attributes correctness and completeness [28].

3) Verification: I have done also this step alone, and by that some of the analysis is at risk of being biased. This threat to internal validity is mitigated by several strategies.

The collection and analysis of the data is based on well known and well grounded theories used in the software engineering field by following the data collection and analysis approaches from Seamen [35].

The research setting with multiple interviews as main data sources surrounded by formal and informal meetings provided the opportunity to continuously validate the results [35], [37], [38].

Continuous validation and short sprints allowed many small adjustments. It was not a big-bang validation during the final validation workshop and no major adjustments were ever done to the artifacts.

The multiple data sources used, documents, interviews and observations provides a triangulation of data [25].

Applying two methodological approaches, SARAD and the interviews provides triangulation of methodology to the results [25].

D. The Methods Combined

Combining the steps outlined above gives three major parts i) SARAD, ii) interviews and iii) workshop.

First SARAD was applied comparing the SimAD and the DD using questions based on the source — channel — destination concept defined by Shannons theory of communication [10], [11]. The data collection was done with an iterative reading of the documents looking for the answers to the questions in the set. The data were analyzed by tabulating the answers. From those tables logical views and deployment views were drawn in order to further visualize the results. The results were verified by a subsequent interview study with the stakeholders, by the rigor of Nord et al. and by basing the question set on a well established theory.

Secondly the interview study was done in six steps

1) Interview with representative from VTI. Validation of evaluation. Partial validation of the refined architecture.
2) Interview with SP5 architect at Viktoria ICT. Validation of evaluation. Partial validation of the refined architecture.
3) Interview with representative for Semcon. Validation of evaluation. Validation of the refined architecture.
4) Interview with representative from Viktoria ICT responsible for the infotainment unit.
5) Second interview/workshop with Semcon representatives validating a partial implementation of the image streaming.
6) E-mail interview with representative for VCC. This interview validated the design and the SARAD evaluation but provided no new data to the design.

Third, a 30 minute workshop with all developers of SP5 present validated the results from the SARAD evaluation and the new design. This process resulted in a validation of SARAD done in each individual interview as well as in the final group session. The design was continuously validated with the interviews and through the final workshop.

The validity of the interview and design study comes from it applying well grounded research methods from the SE field. Multiple data sources and multiple methods provided a triangulation of both method and data source.

IV. RESULTS

In this section I present the three results: i) the evaluation using SARAD, ii) the enhanced design based on the findings from SARAD and the enhancement of SARAD and iii) a comparison of the pros and cons using the first method compared to the enhancement.

A. Results from SARAD

The application of SARAD showed that the following qualities were missing or partial in the SimAD compared to the DD. The results are both direct answers to the SARAD question set and from information found looking for the answers to the questions.

- Recorded scenarios

- Raw signal sources
- No synchronization of the signals to TrustMe
- Refinement of the signals
- Toggle button
- Self driving module
- Active safety module
- Secure gateway
- TrustMe/Aga

The missing qualities are also illustrated by the diagrams in Fig. 6 and Fig. 7. Fig. 8 shows the implemented system in relation to the SARAD evaluation of the DD.

1) Recorded scenarios: The DD requires "pre-recorded data" which should be possible to play back in order to test different types of visualization. This functionality is neither mentioned in the AD nor implemented in the simulator.

2) Raw signal sources and refinement: The original source for the image and data streams that gets visualized by TrustMe. According to the DD those are a front facing camera, radar and lidar. Those are grouped in what is referred to as the "sensing module". In the sensing module are also included the threat assessment and the action plans modules. Those are responsible for fusing the signals from the three sensors and refining them to a list of objects with an assessment of its level of threat in relation to the vehicle and a list of actions the vehicle intends to take based on those threats. From each of those three raw signal sources and the two refinement steps a separate stream should be made available to Trust Me through the secure gateway.

The same raw source signal and steps of refinement are present in the AD. The difference is that they are not considered a combined module. The action plans are a part of the vehicle simulator and the threat assessment is a stand-alone module. The signal paths to the secure gateway are ambiguous since there are two variations of them. The first is like in the DD and the second lacks the tapping of data between refinement steps.

The raw radar and lidar stream directly sent to the secure gateway had no defined destination in TrustMe.

Stated as an important quality of the the video streams and the refined data streams is the ability to synchronize them in such a way that TrustMe can verify that the source data has the same origin in time. A preferred way of doing that is not stated and the quality is not included in the SimAD.

3) Toggle button: A button in the cockpit should be used to toggle the self driving module on and off. That is a requirement from the DD. The button is not mentioned in the SimAD. The type of signal is undefined.

4) Self driving module: The button mentioned in the previous section should toggle the self driving. A self driving module is assumed throughout the documents both explicitly, as with the toggle button, and implicitly in that TrustMe is assumed to run on an autonomous vehicle. Also, the idea of an action plans module implies that there is a self driving module making decisions that can be translated into action plans.

That decision making module is implied in both the documents but the details such as connections to other modules are unclear.

5) Active safety module: In the DD the infotainment unit is required to send signals to the active safety module in order to control the vehicle if the driver does react on warnings from TrustMe. The active safety module is mentioned in the AD and DD where it is placed in the vehicle simulator. It is not implemented in the simulator.

6) Secure gateway: Currently secure gateway handles data from the vehicles internal signals such as velocity and engine speed and the implemented subset of surroundings data. There is a diagram in the SimAD showing that secure gateway should be able to handle data from other networks.

Since secure gateway is based on MQTT it cannot directly handle that kind of streaming video data [18].

7) TrustMe and AGA: In the documents TrustMe is executed on the AGA platform on the infotainment unit.

Signals and the data types that can be use by AGA is defined by the AGA System Data Protocol [19] that is referenced by the SimAD.

There are no signals defined to receive action plans, threat assessments, object lists or a camera stream.

The infotainment device with the AGA distribution is currently connected to the secure gateway.

8) Environment simulator: Both covered by the AD and the DD, the basic version of the environment simulator is implemented and fully connected to the driving simulator. It is also displaying the projection of the simulation on a screen in the cockpit.

9) Driving simulator: The driving simulator is running with a subset of the SPA models of the XC90. It emulates vehicle dynamics and is in the loop with the environment simulator, the DIM and cockpit, the secure gateway and the infotainment unit.

10) Results in relation to RQ1: Applying SARAD to evaluate an AD against a scenario description can be done using a question set based on Shannons theory of communication [10]. When the questions are targeting the modules present in the AD and Scenario description it is possible to get data that can be analyzed by tabulating and drawing architectural views of the system. Those diagrams and the tabulation of the data displays misalignments of the documents.

B. Results from interviews

This section contains the suggestion to a refinement of the SimAD and the DD to align the two documents. To maintain the qualities of the original simulator patterns, the solution aims to adapt to existing structures. How TrustMe can be displayed on the screen (Fig. 3), the final signal destination should also remain unaltered.

The following sections will describe the refined requirements, the solution, and the design rationale for each design decision. The design is summarized by a logical view Fig. 9 and allocation view Fig. 10.
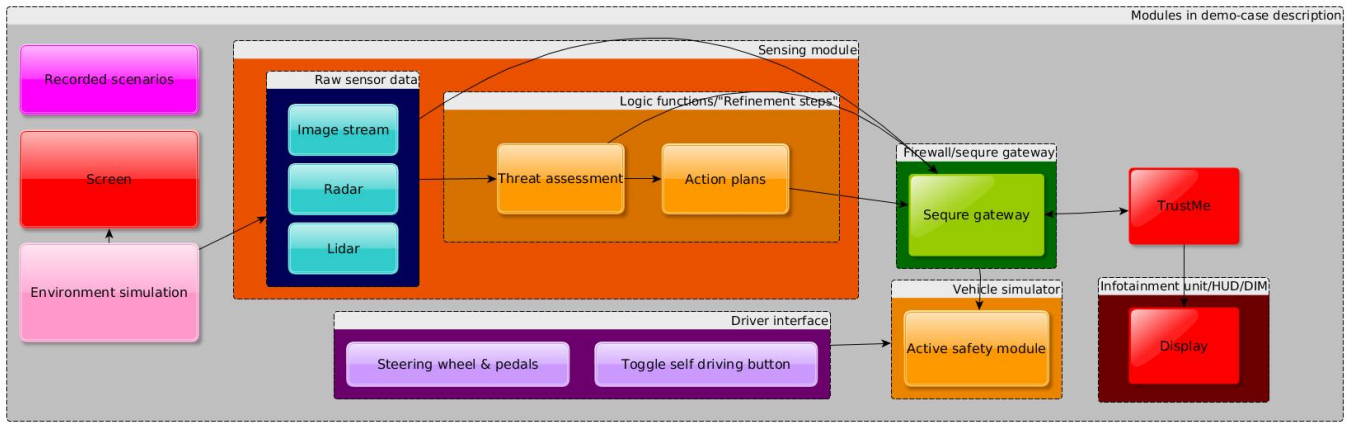
Fig. 6. The logical view according to the data from the SARAD evaluation of the DD.
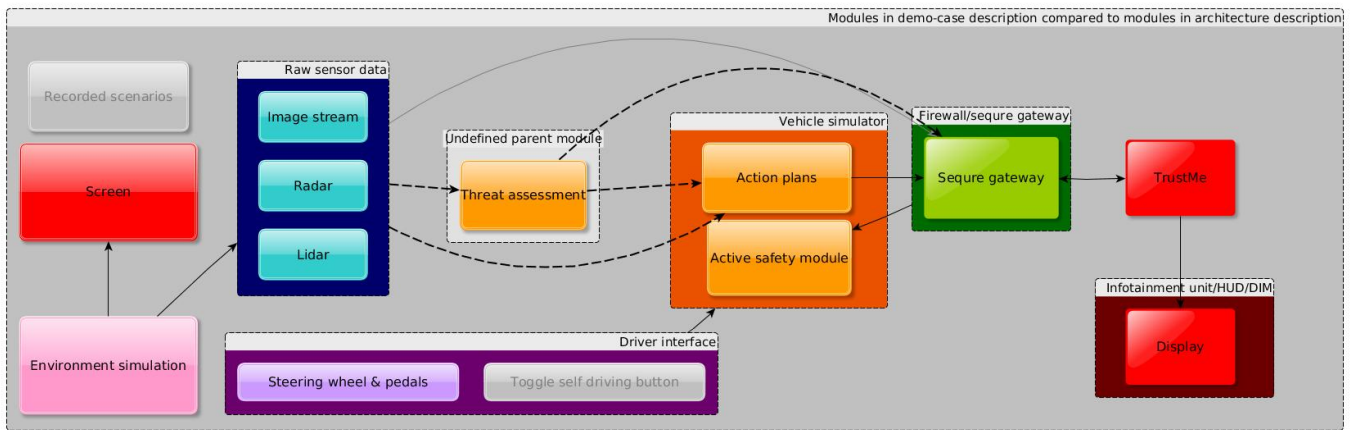

Fig. 7. The SARAD evaluation logical view highlighting differences between the DD and the AD. Dashed lines shows multiple results from the AD, grayed out entities are missing in relation to the DD.
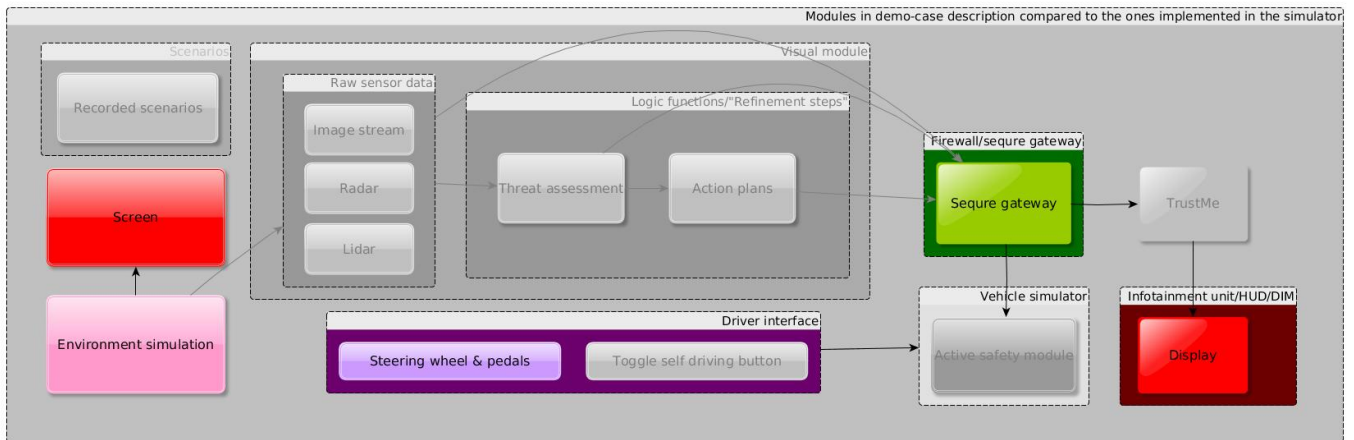
Fig. 8. The evaluation logical view highlighting differences between the DD and the current implementation. Grayed out entities are missing in the implementation compared to the DD.

1) Recorded scenarios: Discussing the problem both in informal meetings and during the formal interviews, this quality was not mainly related to recording of the signals, but rather to the question of a way to achieve reliable repeatability in the simulator. The solution should aim to replicate the signals sent to TrustMe and also have the ability to replicate

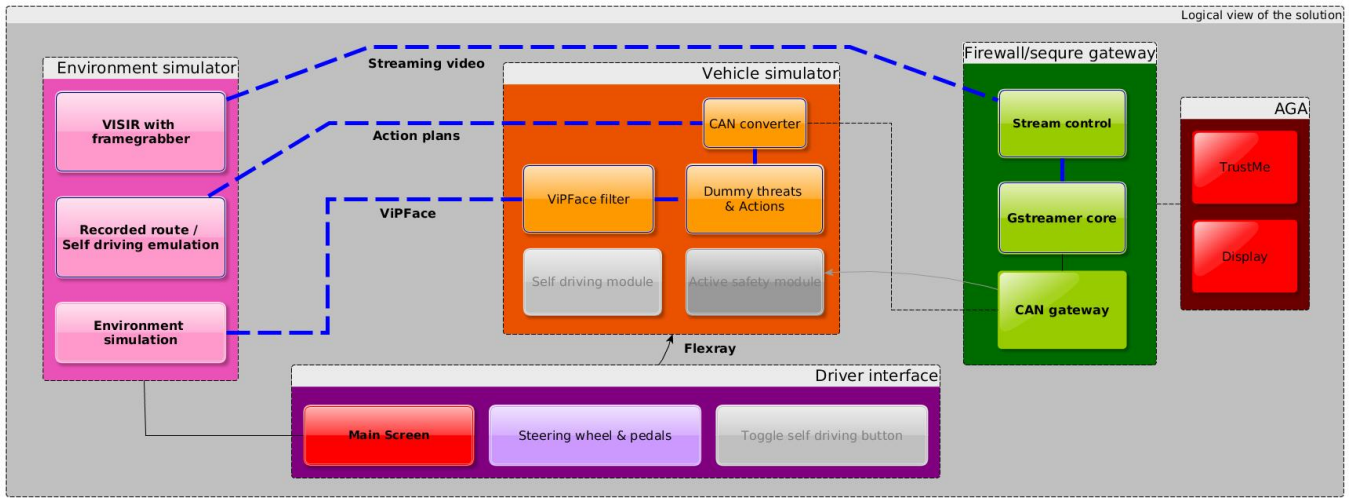Fig. 9. The logical view of the solution including the updates after the verification workshop. Thick blue lines and modules with blue outlines are additions to the system. Dashed lines must carry the RTC timestamp unaltered from the source.
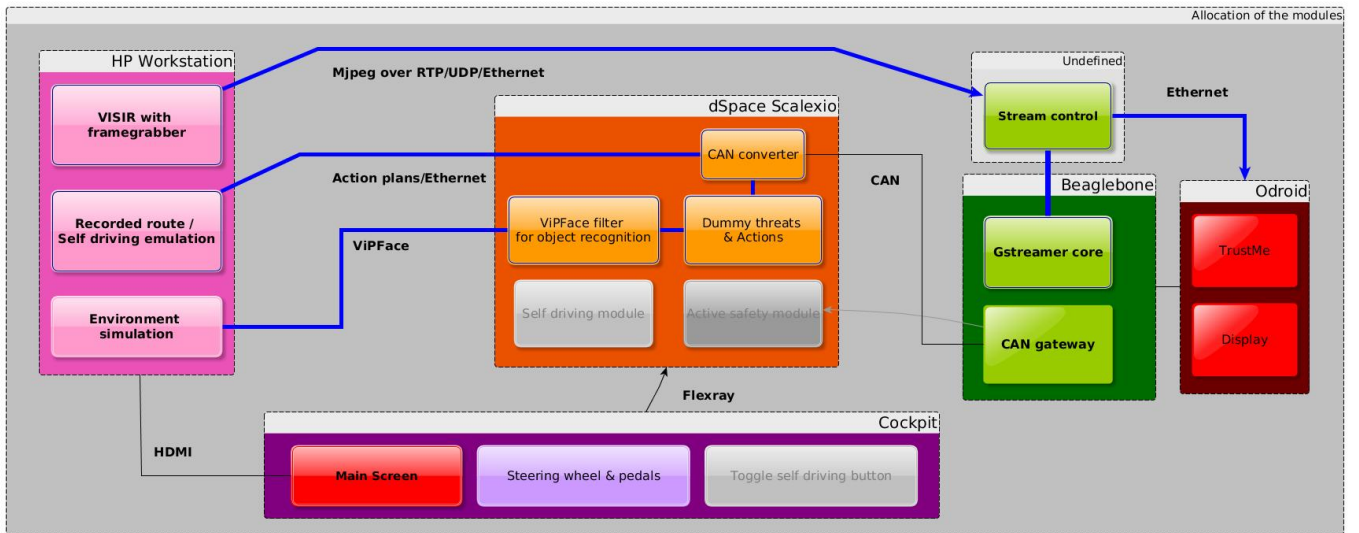

Fig. 10. This allocation view of the solution including updates after the verification workshop. Thick blue lines and modules with blue outlines are additions to the system.

the entire simulation.

Looking at other vehicle simulators shows similar approaches. The simulator control is what can be used for repetition, not a recording of output data [39], [40], [41].

VTI presented a solution where the simulation core of the environment simulator was re-programmed with the option to force a vehicle to follow the road in a predictable way.

This approach would fulfill the requirement of replicating the output to TrustMe. It would also provide the opportunity to repeat data sent to the vehicle simulator and the secure gateway.

The trade offs with this solution is that since the environment module is controlling the path of the vehicle the feedback from the vehicle simulator simulating vehicle dynamics will be

unused. It will also require a reprogramming of the simulation core in order to "record" each new driving path.

2) Raw signals: This section is extensive and divided into subsections. First is the refined requirements related to raw signals. Second is the solution and rationale for raw radar and lidar sources, raw image source, image network transport protocol, image compression format and synchronization of the feeds.

a) Refined requirements: The requirement of raw radar and lidar data in the DD is vague. The "rawest" use case that was discussed in the project is a user developing a new sensor fusion algorithm or exploring a new radar module. This use case is beyond the scope of TrustMe but relates to the generality of the solution.

From the informal and formal meetings the requirement of a raw camera feed has been specified further. What is required is a video feed in a refined but unspecified format. The image crop should be equivalent to what would be registered by a front facing camera. At one of the formal meetings the requirement of the feed was extended to also make it generally available to the Vehicle simulator, not only to supply the sensor fusion and TrustMe with visual data.

The interviews provided some desired qualities of the stream not covered by the SimAD or DD. A summary of those requirements is that the video is real time and the solution can be generic using standard protocols and algorithms, preferably open source. A request from Semcon was that it should be computationally cheap and permit encryption of the data in order to be secure in a cloud connected vehicle. The definition of real time is a delay that is not humanly perceptible.

The interviews showed different views on the need to synchronize the feeds. The Semcon representative argued that if the streams needed to be synchronized they had passed their deadline. The opinion from the Viktoria AGA representative was that the streams needed the option to be synchronized and that the integrator was the one to decide if it was used.

b) Radar and lidar sources: Within the project is an ongoing effort to export surroundings data from the environment simulator in what is called the ViPface protocol. The VTI representative stated that it is possible to include objects similar to what would be detected by a radar and a lidar in ViPFace. The proposed solution is to enhance ViPFace to include all objects a sensor fusion of radar, lidar and image recognition would detect and at this stage omit the raw data.

Looking at how autonomous research vehicles process sensor data from radar shows that the algorithms require either output from an A/D converter in the radar antenna or a refined data structure of objects with distances and angles [42], [43], [44], [45], [46]. This is much less refined than the signal from the ViPFace. The proposed solution would make the simulator less attractive for use cases which need low level radar and lidar signals.

The interviews showed that the likely input to a radar or lidar simulating module outputting data types more aligned with the low level signals used in the research vehicles, would be similar to the ViPFace output.

If the project decides to further extend the simulator to a more generic solution by obtaining radar and lidar simulator modules this proposed solution provides possible extension points since the ViPFace data is a realistic input required by those modules.

c) Raw video source: Since the need for raw data from radar and lidar is circumvented by the proposed solution, the use of the video feed for object extraction gets omitted. But the requirement to display the stream on the infotainment device remains.

According to the interview with the VTI representative it is possible to run more than one instance of Visir on the same simulation, providing two different projections of the

simulation. One instance is showing the view on the main screen. One additional could mimic a front facing camera.

A screen grabber is a type of image sampling software that can convert the content of a GUI window to a video stream. Using a screen grabber on the extra Visir instance will allow it to be used as a video source.

d) Network protocols: RTP (Real time transport protocol) is a standard defined by the Internet engineering task force. It provides end-to-end network transport functions "suitable for applications transmitting real-time data, such as audio, video or simulation data, over multicast or unicast network services" [47]. RTP has open source implementations [48] among one is an integrated part of the Android system [49].

The actual media payloads transported by RTP can be adjusted to accommodate a number of different qualities.

There is an equivalent encrypted version of the RTP protocol. SRTP (Secure real time transport protocol) implements RTP with a layer of encryption [50]. There is an open source implementation of that protocol [51].

Sending RTP using UDP on an IP network can fulfill many of the required qualities. It provides a protocol that has an open source implementation, it is available on the Android platform and allows a variety of payload types. Using an IP network will also allow interfacing with the Odroid and Secure gateway.

e) Media payload: Mjpeg is a video format consisting of a stream of Jpeg compressed images. It is computationally cheap to compress and has a long history of use in for example IP cameras [52]. It is also implemented on the Android platform [53]. Mjpeg provides the option to include a timestamp with each frame through the EXIF meta data to support a synchronization solution. Mjpeg is also a scalable format which can be encrypted using a computationally cheap method [52].

f) Synchronization: A real time clock (RTC) time stamp sent with each object data and each frame of the image stream can be used to synchronize the signals.

The same RTC time on two separate feeds could be obtained by deploying the software on the same computer or by synchronizing distributed computers with an NTP server. The NTP solution is used by VTI in simulator setups. That timestamp can later be used to synchronize the streams in TrustMe.

The interviews showed a discrepancy in the need for synchronization. Since the strong opinion to include them originated in the interview with the actual integrator of the stream, that opinion was given a higher weight in the design decision to include the timestamp.

g) An integrated solution: Gstreamer is an open source tool for manipulating streaming media. It supports a variety of payload and transport protocols which can easily be changed to any of the suggested formats [54]. It also includes a screen grabber and modules to send the streams using RTP. To integrate gstreamer in the simulator would both provide a direct modular solution to much of the streaming needs

and points of extension for the system by allowing advanced control of streaming media.

3) Object recognition & threat assessment: Getting the surroundings data directly from the environment simulator through ViPFace will omit the need for the more complex parts of the object recognition such as extracting object classes and positions from fused sensor data.

The suggested solution is to filter the data from ViPFace to appear equivalent to the data from an object recognition module. The strategies for obstacle detection in autonomous experiment vehicles are varying. In some case the cameras are adjusted towards the object of interest [55], [56], in another case the area of interest changes depending on the speed of the vehicle [45]. Which filtering strategy is chosen needs to be decided within the project.

The threat assessment can also be simplified considering that TrustMe mainly is a visualization scenario and does not aim to implement the actual self driving functionality. The distance to the vehicle and the type of object could be the parameters used for setting a threat level to each object.

This requires a change in the DD. There the signal sources are assumed to be supplied from the three sensors.

The deployment of the dummy modules are on the Scalexio. They are coupled with the vehicle simulator and need to access safety critical parts.

To use the CAN-bus as channel for the output signal is adapting to the existing architecture for vehicle data sent to the secure gateway. The exact format of the signal needs to be negotiated further by the team.

4) Secure gateway: MQTT requires an extension of the broker to allow it to turn on and off IP streams. The interviews didn't result in a complete solution and the details of this has to be negotiated further. The current research provides little guidance. The idea of having an infotainment/non safety critical part of the vehicles network differs from solutions presented by for example Narzt et. al [57] Yoo et al. [58] and Sonnenberg et al. [59]. In those architectures the infotainment unit have a dedicated camera unit [57] or is trusted to only interact with the vehicle signals in secure ways.

A possible solution is using functionality in gstreamer to control and forward the stream. A MQTT-client receiving messages from the broker can control what stream is forwarded to what recipient.

The properties of the deployment hardware needs further considerations.

5) Self driving module and Action plans: It is not within the scope of the Second Road phase 2 project to develop such a self driving module.

As the written answer from the VTI representative stated in relation to the action plans from such a module: "This is the type of stuff the car industry spends millions trying to develop."

The proposed solution for a repeatable simulation is to program the environment simulator to force a vehicle to follow a road. The interview with VTI determined that it also can be used in order to emulate the behavior of an autonomous

vehicle by hardcoding speed changes, stops and avoidance maneuvers.

This will of course include the trade offs discussed in the recording/replaying of simulation data, namely the loss of vehicle dynamics.

6) Toggle button: Omitting the self driving module, the signal from the toggle button mentioned in the DD looses its destination. This button was not discussed further during the interviews.

7) Active safety: From the interviews, the signal sent from the infotainment unit to the active safety module was identified as a problematic use case. The Viktoria AGA developer stated that the use case of letting the active safety unit be controlled from the unsecure side was identified as potentially dangerous by industry representatives. The need to pass a signal from the unsecure side to the secure is the quality targeted by the scenario. In the formal meetings it was discussed plans to implement signals sent in that direction prior to TrustMe. Considering this the active safety unit is further disregarded in this solution.

8) Aga/TrustMe: To handle the object and action plans stream the AGA API needs to be extended to include those signals.

Regarding streaming images AGA contains no built in formats, as stated in the AGA documentation [19]. The suggestion from the AGA responsible at Viktoria was to circumvent AGA and use native Android library functions.

9) Results in relation to RQ2: The design decisions are summarized in two architectural views. One logical view and one deployment view as shown in the diagrams 9 and 10.

To extend a SARAD evaluation to also lead to an alignment of the documents and a design that accommodates the missing qualities the following steps can be used:

- Apply the SARAD evaluation as in RQ1.
- Use the results from the SARAD evaluation as a map of where qualities are missing of the design.
- Iterate the development of the new design with interviews of representatives for developers of each module of the system. The interviews should include the evaluation and the current iteration of the design. The aim is to both validate the artifacts and gather data for the next development step.
- Validate the final refined design by a final workshop.

C. Comparison of the two approaches

This section first displays the results from the comparison of the two approaches and then shows how they relate to RQ3.

1) Basic SARAD compared to the refinement: Applying SARAD by comparing an AD with a scenario description resulted in a partial map. This map showed where parts of the system are missing, where there are clear misalignments between the two documents in terms of signal source, signal channel and signal destination. A map of that kind is no guarantee that the aligned areas are problem free. But a defined source, channel and destination shows that the aim of the two

documents align. From that it has been possible to identify problem areas in the design and what potentially is fine.

This was a valid starting point for the design process and a guide to tailor the interview questions towards the right areas of the system.

Time consumption is also a positive effect of the document approach. The initial SARAD evaluation was complete within 60 working hours. That could be done without participation of other parties. The time spent was only that of one person and how the time was disposed was easy to control since it did not need to be coordinated with others.

It was first with the interviews that it was possible to show what actually was missing, if it was important qualities and how it was possible to accommodate those qualities in the design. Or if the scenario should be changed instead.

The interviews also provided new refined information of the system and the requirements which was not included in the documentation or revealed by the SARAD evaluation.

The SARAD evaluation provided refined information of the system on a conceptual level by showing that parts were missing. The interviews provided refined information on both the conceptual and detailed level by providing more granular information on the actual requirements of each module in the simulator. They also helped filter out which missing qualities were important, such as the secure gateway, and which were not, such as the toggle button.

The final validation of the design was quick, the meting required 30 minutes. And the continuous validation during development was integrated in the interviews.

I have entered this project as the most junior without prior knowledge of the system and with shallow domain knowledge. Considering that, one apparent upside to both parts of the methodological approach is their light weight and ease of use. I have in a relatively short time been able to analyze the system and provide a refined design.

Using the interview enhancement also resulted in positive effects in the organization. Having the most junior developer act as a coordinator and facilitator to the design used by a distributed team was met by enthusiasm from the team members. During the validation workshop they expressed that this way of working both allowed them to focus on their own parts and provided ease of mind. They didn't have to worry about or spend time on coordination. One member said that he would like to work like this again. This should be contrasted to i.e. Krutchen who states that the architect must have "significant experience in software development" [60]. On the other hand Krutchen also warns that the most senior authority isolated in an "ivory tower" is a common anti pattern of SA practice [61].

The approach also increased the teams understanding of the system. The process itself automatically includes the spreading of architectural knowledge. In each interview the team members to some extent had to be reminded of the contents of the SimAD and the DD. The refined information gathered during the process was also spread. It occurred through that rationale for the current design had to be presented in each interview. "There were a lot of things we didn't know about our simulator" was one team members reaction.

This has spread information about the system across the distributed organization. Team members can work on different domains but still have interest in the same information, for example regarding image streams, to accomplish their tasks. This is along the same lines as Spotifys approach to scale agile by promoting cross team groups [62].

Spreading architectural knowledge is an important but often forgotten architectural task [8]. The process included gathering of new information and spreading it with the intention to directly get a response leading to a design solution. From that the task I had could be viewed as a refinement of the tasks defined by Martini et al. [8]. The model by Martini et al. gathers opinions from team members and propagates them upwards to the architect allowed to make the proper design decision. Here they were a direct base for the decisions.

The role of the architect in relation to Martini et al. was also refined by this way of designing. The design process was done mainly at the level of team architect, but decision of stream formats and signal paths through the system are inter-feature decisions. And they are the domain of the governance architect.

Agile development is done in small self organizing teams. In agile environment the aspects of the architecting process is often moved from the architect in the ivory tower to the implementing self organizing team [63]. This way of developing architecture gathers the collective knowledge of the team and uses that as a starting point for implementation. Subsequently the team showed commitment by i.e. providing solutions to problems outside of their own scope.

2) Results in relation to RQ3: The positive aspects of the SARAD only evaluation are:

- Fast
- Lightweight
- Provides a starting point for a refined design
- Easy to use
- Shows areas of alignment/misalignment
- Can be done by one person

And the negative aspects are:

- Aligned areas are not verified
- Displays gaps in a design, but not exactly what is missing
- No noticed effect on the organization

The positive aspects of the enhanced method are:

- Verifies aligned areas
- Results in a design
- Gives team commitment
- Allows developers to concentrate on their own domain
- Collects and spreads architectural knowledge
- Also lightweight and easy to use

And the negative:

- Requires the attention of several team members
- More time consuming compared to SARAD

V. Discussion

This section discusses the results from a few viewpoints such as their validity and in relation to previous work.

A. Verification

The results of this study is verified in several steps. The application of SARAD to review an AD from the perspective of a scenario description was verified both by the interviews and by that the result could be used as a starting point for a new design. That design was in turn verified by triangulated data from interviews, meetings and a workshop. This is described in sections III-B7, III-C3 and III-D. A partial implementation of the streaming solution using gstreamer was demonstrated and validated separately with the Semcon representative.

Using this method to compare document and enhance a design from the result from the first step opens for continuous and repeated validation of all artifacts during the development phase.

This method is also a small step from current practices when it comes to evaluating both architectures and architectural descriptions. The use of scenarios and questions are well established approaches [3]. The way this approach differs is mainly in the goal of the evaluation.

The robustness of this application of SARAD is dependent on the quality of the documents. The better they describe the system the more you are likely to trust the results. This must be accounted for in the analysis of the significance of the results.

B. In related work

One of the important qualities of architectural evaluations is reusability [2], [3]. In this case areas of usability are the method itself and the way to create the question set. In both of these areas this study has aimed for generic solutions based on proven theories.

As Bareclos et al [3] point out: The results of an ad hoc inspection of the documents is highly dependent on the skill level of the one performing it. That claim is supported by that this structured method could be performed by someone without previous domain knowledge. They also suggest that reusability is important when constructing question sets for evaluations. Anchoring the questions in Shannons well used theories [10], [11] places them in a theoretical framework that opens for reusability.

The misalignments in the documents posed risks of different levels to the implementation of the project. Finding some of them first using SARAD and then through the enhancement is strengthening the statement by Knodel and Naab that evaluations can be an important method to mitigate risks before changing a system [23]. Also in line with their research is the result that AD:s rarely contain all the information needed in order to address all architectural requirements [24].

C. Source — channel — destination

The over a half century old theoretical framework from Shannon [10], [11] could be applied to analyze a modern information system. The simplicity in the theory contributed to the ease of which I as a junior developer could analyze the system. It's usefulness also comes from the ability to apply a general framework to analyze the system from common denominators. At the same time it is general enough to not restrict the form and content of the analyzed entities. It was equally useful on a simple display unit as it was on a complex logical module.

The framework was applied on the case system on different levels of abstraction while developing and using the question set. It proved useful to analyze the scenario from the high abstraction level of raw signal sources of radar, lidar and image to the final display of their refinement by TrustMe as in section IV-A2. It was also useful to analyze the relation of modules at decreasing level of abstraction as in section IV-A5.

D. Scaling outside open and agile environments

SP5 is not the standard development organization since it is part of a research project using agile methods in a team distributed over several organizations. To use this methodology in another context or a larger project could be a next step.

Without prior knowledge of the system I was required to gather and synthesize large amounts of information from the system itself and from refined design suggestions.

From that I also had to weight pros and cons of many aspects of each solution. All of the resulting design decisions includes a weighting of this new information. For example the chosen Mjpeg video format was weighted against other formats with similar properties such as H.264, Mpeg 2 and VP8/VP9. The need to process all this new data could make the method too time consuming in a larger project.

The openness and willingness from the team members to provide me with help and information is also a factor. In this project the method resulted in increased commitment where I for example was invited to the second meeting with the Semcon representative to demonstrate and refine the streaming concept originating in the VTI interview and my proposed solution.

In a more closed and hierarchical organization, a junior developer suggesting a system solution could have been received in a negative way.

Also scaling it to larger projects could prove challenging since Breivold et al. points out that agile methods often are insufficient in supporting complex architecture [7].

The small organizational size and openness of SP5 can also explain why the roles defined by Martini et al. [8] needed to be refined. The case companies from Martini et al. are described as "multi team" indicating that they are significantly larger than SP5. This refined position, between governance architect and team architect, resulted in gathering and spreading of architectural knowledge. The latter a problem area according to Martini et al. [8].

VI. Conclusion & Future research

The aim of this study was to see how SARAD could be used to evaluate an AD from a scenario description. Subsequently

the approach was enhanced in order to not only show missing qualities but also find which those qualities were.

This aim was reach by first applying SARAD on the AD from the Second Road phase 2 by comparing it to the Demo-case description for the scenario Trust Me. This was done using a question set based on the tested source-channel-destination-theory [10]. The results from the application of SARAD were verified by interviews with the developers and by an enhancement of the original AD.

The application of SARAD resulted in a light weight evaluation of the AD. The resources consumed were less than compared to if interviews with the stakeholders would have been used throughout. The extension of the method resulted in a verified design. During the process the interviewed representatives of the team showed a high level of engagement and at the validation workshop it was said that they "would like to work like this again".

The organization around this is special in that it has no clear product owner and is relatively small. It is an open question how this way of working would scale to larger projects and other types of architectural documentations. That could be a starting point for future research.

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