

# **A Method for Identifying Architectural Solutions for Potential Intelligent Goods Services**

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## ABSTRACT

### **Purpose of this paper**

This paper presents a method for identifying possible architectural solutions for potential intelligent goods services. The solutions range from implementing all service intelligence at the goods level to requiring no goods intelligence at all. The paper also shows how different solutions, identified by the method, can be compared and evaluated through quality analysis in order to determine when intelligent goods are beneficial.

### **Design/methodology/approach**

Literature and case studies, and theoretical analyses form the foundations of the paper. The method is based on a general framework for describing intelligent goods systems, which involves several levels of intelligence related to both the goods and the local entities surrounding the goods. Three specific services are used to illustrate the method. The quality analysis is based on the Analytic Hierarchy Process (AHP) and a number of proposed quality attributes.

### **Findings**

The paper illustrates how the framework can be used to identify relevant architectural solutions for a particular service, with different levels of intelligence on the goods. It also shows how to qualitatively analyze individual solutions and suggests an extension to the general framework for describing intelligent goods systems.

### **Research limitations/implications**

The paper does not contain measured data to base the quality analysis on. Testing the method and quality analysis on implemented cases is recommended for future work.

### **What is original/value of paper**

The novel method and approach for identifying and evaluating architectural solutions for potential intelligent goods services, are useful in general management when investigating the value of implementing intelligent goods. The paper also contributes to the description of intelligent goods systems.

*Keywords: Intelligent goods, Smart goods, Architecture, Transportation, Distributed intelligence*

# 1. INTRODUCTION

In general, the concept ‘intelligent goods’ refers to goods with some level of intelligence implemented on or close to the goods. It hereby represents a further development of bar codes or the simplest forms of RFID tags. Just as Artificial Intelligence initially was focused on how to replicate human intelligence in a machine, intelligent goods derive from the idea of making the goods, to some extent, act as human travellers. For instance, one of the visions is to make the good able to, by themselves, find the best and fastest way to reach their destinations (including route choices, transport modes, time schedules, costs etc.). Such scenarios require a relatively high level of distributed intelligence (see section 2) and agent-based computing therefore represents one possible implementation alternative. The overall purpose of the concept intelligent goods is to use it as an instrument for a more efficient future transport system.

The characteristics of intelligent goods differ slightly between different studies and different denotations are used for concepts similar or identical to intelligent goods (Euridice (2009), Huschebeck *et al.* (2009), Holmqvist and Stefansson (2006), Lumsden and Stefansson (2007), Johansson (2009)). In this paper, intelligent goods is defined as in (Jevinger *et al.* (2010)), which means that the definition involves different levels of intelligence connected to the goods (see section 2). The definition is furthermore a part of an intelligent goods framework which is extended, in this paper, into also comprising the corresponding levels of intelligence of the local entities surrounding the goods (e.g. pallets, transport containers, vehicles). The reason for this extension is that the results of the method presented in this paper include different combinations of levels of intelligence on both the goods and the surrounding entities.

In order to find the best solution for a service, solutions based on intelligent goods should be compared with other solutions in terms of costs, service quality etc. Furthermore, different implementations of intelligent goods also need to be compared. In particular, each implemented combination of levels of intelligence on the goods and the surrounding entities, may enable more than one physical architecture (Hong *et al.* (1995)). The purpose of this paper is to lay the foundation for such analyses, by proposing a method for how to identify the architectural solutions for potential intelligent goods services. We believe that this method can be useful in general management when investigating the value of implementing intelligent goods, for instance, when deciding whether to invest in intelligent goods and to what extent, and which level of intelligence to implement.

In this paper, we denote each allocation of service functions and communications, in combination with the required levels of intelligence, as architectural solutions. Each architectural solution hereby includes a specification of the minimum levels of intelligence of both the goods and the surrounding entities, as well as the communication paths, the information to be transferred, service functions etc. The architectural solutions, furthermore, range from pure intelligent goods based, to requiring no intelligence on the goods at all. As a basis for this architecture analysis, we use three specific services; two representing some important functionalities required by the practitioners (as has been shown by various studies, e.g. (Lumsden and Mirzabeiki (2008)), see section 3), and one reflecting the more visionary idea about goods finding the best transport, presented above. We also propose a number of quality attributes for the services (e.g. time for output information to reach recipient, amount of required wireless communication, level of integrity). The paper ends by showing how these

quality attributes can be used to evaluate and compare the different solutions on a theoretical and functional level.

The paper outline is as follows. Section 3 presents the extended intelligent goods framework. Section 4 describes the architecture analysis by first presenting the three selected services to analyze. The method for how to find the corresponding architectural solutions is presented and the resulting solutions are shown. In section 5, a number of quality attributes are listed and the architectural solutions are analyzed with respect to these. Finally, in section 6, the results are concluded.

## 2. EXTENDED INTELLIGENT GOODS FRAMEWORK

Among the previous definitions of intelligent goods, the one presented in (Jevinger *et al.* (2010)) differs from the others since it is based on different levels of intelligence, reflecting the various types of capabilities the goods may have. The capability types are represented by a number of dimensions, each including a number of different levels of intelligence. In this paper, we use these dimensions to describe the minimum capabilities of the goods in our architectural solutions. However, an architectural solution includes a specification of the capabilities of both the goods and the local entities surrounding the goods (see section 1). In (Jevinger *et al.* (2010)) the word container is used to represent the local entities surrounding the goods (e.g. enclosing package, transport container, vehicle). The container may hold either goods or other containers. Moreover, the building (e.g. warehouse or terminal) or vehicle (e.g. truck, ship, train or airplane) in which the goods might be located is considered as the outmost container and is there denoted as housing. In this paper we will use a slightly different terminology; we denote containers as housings and the outmost container as simply the outmost housing. The purpose of this is to avoid the word container, since it might be confused with shipping containers, which only represent a subset of what is intended. The extended framework presented in this paper hereby specifies all essential levels of intelligence of both the goods and the housings, see table 2.1. The capability levels related to the housings are slightly more coarse-grained than the ones related to the goods. For instance, a minor capability change in all goods entities usually represents a more significant alteration than an equivalent change in the vehicles.

The order in which the capabilities are listed within each dimension in table 2.1 corresponds to the level of intelligence, i.e. a lower number indicates a lower level within the same dimension. The level of intelligence corresponding to 1, form a set of lowest level capabilities, and as in (Jevinger *et al.* (2010)), we suggest that all goods, whose capabilities lie above this lowest level (i.e. above 1 in at least one dimension), should be considered as intelligent. The lowest level includes for instance bar codes and the simplest form of RFID tags. Table 2.1 furthermore shows that both the housings and the goods are required to have an ID. These IDs are static and are required since they identify the goods and the corresponding housings throughout the whole transport. On goods level, one ID may represent several goods units as long as they all belong to the same consignment and share the same origin and destination address. In our studies, we assume that the capabilities of the goods along with the ID and other necessary information entities, will follow the goods throughout the whole transport. These capabilities can be implemented either on the goods themselves or close to the goods, e.g. on a pallet or a transport container accompanying the goods. Finally, please note that the sensor capability (G in table 2.1) in the form of position sensor is unnecessary when the

housing is a terminal or a warehouse. The corresponding capability would in this case be statically stored information about the position of the terminal/warehouse.

Table 2.1 Capability dimensions for goods and housings respectively

<b>Goods</b>	<b>Housings</b>
A. Memory storage 1. Ability to store ID 2. Ability to store goods data (other than ID) 3. Ability to store algorithms/decision rules	A. Memory storage 1. Ability to store ID 2. Ability to store data and algorithms/decision rules
B. Memory dynamics: 1. Static memory 2. Ability to change/add/delete data (other than ID) 3. Ability to change/add/delete algorithms/decision rules	B. Memory dynamics: 1. Static memory 2. Ability to change/add/delete data and algorithms/decision rules
C. Communication out: 1. Data (including ID) can be read by external units (e.g. barcode, simple RFID) 2. Ability to send short-range messages 3. Ability to send long-range messages	C. Communication out: 1. None 2. Data (including ID) can be read by external unit (e.g. barcode, simple RFID) 3. Ability to send short-range messages 4. Ability to send long-range messages
D. Communication in: 1. None 2. Ability to receive short-range communication messages 3. Ability to receive long-range communication messages	D. Communication in: 1. None 2. Ability to receive short-range communication messages 3. Ability to receive long-range communication messages
E. Processing: 1. None 2. Ability to execute decision rules (e.g. If –Then statements) 3. Ability to execute algorithms (e.g. planning capability, optimization algorithms)	E. Processing: 1. None 2. Ability to execute decision rules (e.g. If –Then statements) 3. Ability to execute algorithms (e.g. planning capability, optimization algorithms)
F. Autonomy*: 1. None 2. Reactive capability (actions must be triggered by an external unit) 3. Proactive capability (no external trigger needed)	F. Autonomy*: 1. None 2. Reactive capability (actions must be triggered by another entity) 3. Proactive capability (no external trigger needed)
G. Sensor: 1. None 2. Sensor capability incl. ability to read sensor data (e.g. temperature or position)	G. Sensor: 1. None 2. Sensor capability incl. ability to read sensor data (e.g. temperature or position)
H. Time: 1. None 2. Ability to measure time intervals 3. Ability to determine actual time	H. Time: 1. None 2. Ability to measure time intervals 3. Ability to determine actual time

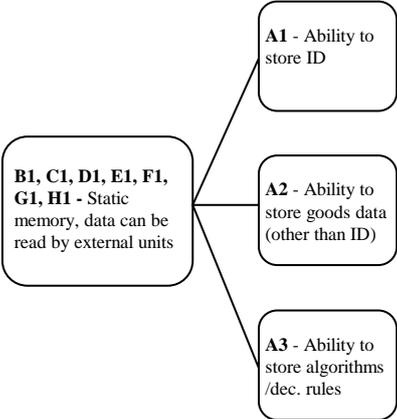
\*) Bar codes and simplest form of RFID tags are not considered as reactive since they are simply scanned by a reader.

There are several dependencies between the different capability dimensions. For instance, the ability to execute decision rules has to be combined with at least the ability to store decision rules. In table 2.2, we list all such dependencies related to the capability dimensions of the goods. An almost identical version of this list has been presented (Jevinger *et al.* (2010)). Based on table 2.2, and the capabilities presented in table 2.1, we have identified the set of all valid combinations of capabilities. Apart from the combinations excluded due to the

dependencies, a few redundant combinations have also been removed. This process has overall decreased the number of combinations from 4374 to 327. Figure 2.1 shows the result, which hereby represents all possible levels of intelligence included in the concept intelligent goods, as suggested in this paper. Naturally, the same procedure can be performed for the capability dimensions related to the housings. However, in this paper we have chosen to focus on the goods, and in particular the intelligent goods definition, and we hereby leave out the dependency investigation of the housings.

Table 2.2 Dependencies between the capability dimensions of the goods

Capability	Required capability
Memory dynamics: B	Memory storage: A $\geq$ B
Communication out: C > 1	Memory storage: A = 3, Processing: E > 1
Communication in: D > 1	Memory storage: A = 3, Memory dynamics: B > 1, Processing: E > 1
Processing: E > 1	Memory storage: A = 3, Memory dynamics: B > 1, Autonomy: F > 1
Autonomy: F = 2	Memory storage: A = 3, Processing: E > 1, Communication in: D > 1
Autonomy: F = 3	Memory storage: A = 3, Memory dynamics: B > 1, Processing: E > 1, Time: H > 1 or Sensor: G = 2
Sensor: G = 2	Memory storage: A = 3, Memory dynamics: B > 1, Autonomy: E > 1
Time: H > 1	Memory storage: A = 3, Memory dynamics: B > 1, Autonomy: E > 1



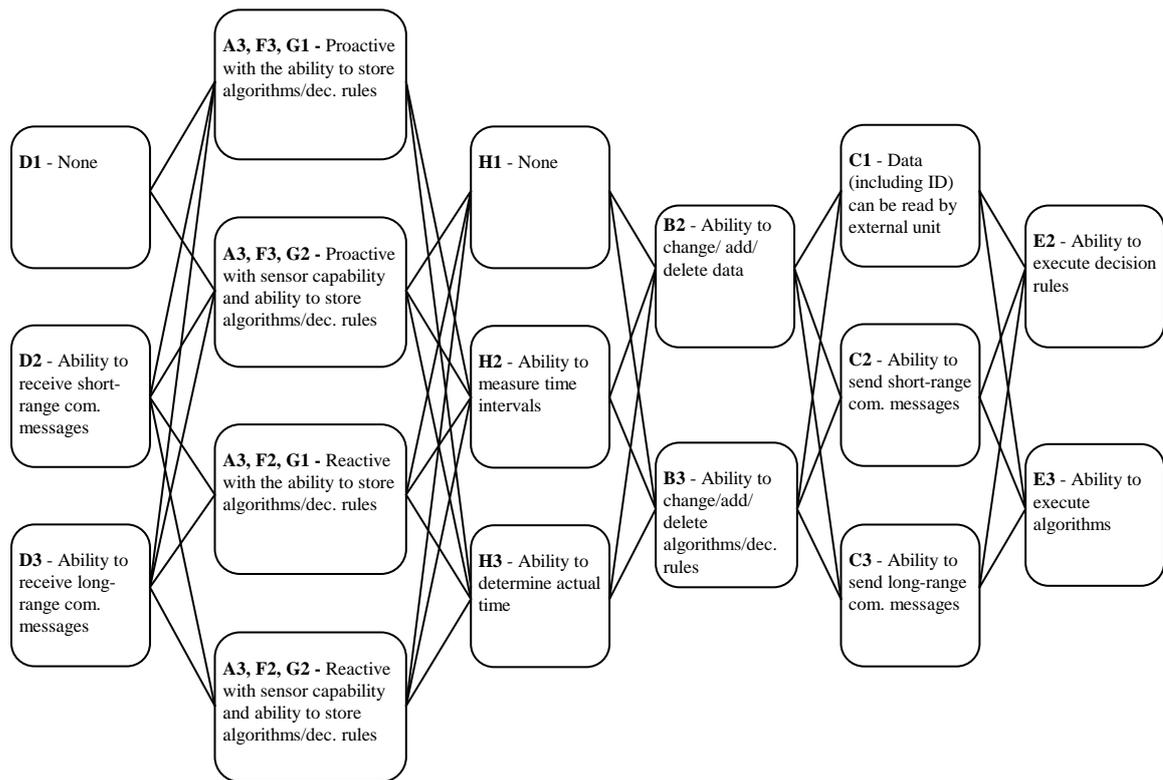


Figure 2.1 All levels of intelligence included in the suggested definition of intelligent goods

### 3. ARCHITECTURE ANALYSIS

Based on the capability dimensions, solutions for different services can be identified and compared against each other. In order to find the best solution, we must begin by identifying the set of all possible solutions for each service. The method for identifying the architectural solutions can hereby, in short, be described as follows. By using the intelligent goods definition from (Jevinger *et al.* (2010)), the set of all valid combinations of capabilities of the goods can be identified, as shown in figure 2.1. Based on this set, and the extended framework concerning the housings, we may identify all possible combinations of levels of intelligence on both the goods and the housings for a particular service in question. At the same time the communication paths necessary to fulfil the service requirements are identified. From the resulting set of solutions, the redundant or unrealistic ones should finally be removed. The method has primarily been developed based on literature studies, case studies (e.g. Mirzabeiki *et al.* (2010)) and in-depth analysis of the intelligent goods definition. The method, together with the three illustrating services, has also been discussed at a workshop on intelligent goods, with both practitioners and other researchers. It has however not been tested on implemented cases, mainly because goods examples of advanced implemented intelligent goods services are hard to find. In this section, we will use the three services to show how the method can be applied. The three services, together with some information about why they have been selected, are presented below<sup>1</sup>.

<sup>1</sup> In comparison to the basic potential intelligent goods services in (Jevinger *et al.* (2010)), these services can be seen as higher level services since they incorporate the basic services as parts of the complete functionality.

### **1. Misplaced goods are detected and reported**

**Description:** Goods that are placed in the wrong housing (forgotten to be unloaded or loaded, mistakenly loaded or unloaded, stolen etc.) are detected and reported. The service is primarily based on information about the specified itineraries of the goods and the vehicles, and information about which actor is assigned responsible for the each part of the transport. Deviations are reported upon request to a local questioning unit (operated for instance by a driver or a terminal worker), or continuously as directed or undirected messages, depending on implementation.

**Motivation:** Errors due to loading and unloading the wrong cargo sometimes cause considerable problems (Huschebeck *et al.* (2009)). Furthermore, using this service for detecting and tracking stolen goods, may prevent high costs. For instance, the amount of direct costs resulted from theft of cargo and/or freight vehicles in the European Union was estimated to more than 8.2 Billion EUR per year, in 2007 (European Parliament report (2007)).

### **2. Condition and route deviations (e.g. for dangerous goods) are reported in real time during transport**

**Description:** The service sends reports on goods whose physical conditions (e.g. temperature, vibrations) exceed or fall below certain goods specific limits or whose route deviates from the one stipulated. It is based on the goods itinerary and position, and data from local condition sensors. Deviations are reported to both ERP (Enterprise resource planning) systems and housings, and further sent to a questioning unit upon request.

**Motivation:** Studies show that practitioners value information about the location and condition of products in shipment high (2nd and 3rd most important types of information according to (Lumsden and Mirzabeiki (2008)). They also show that experts view self and context awareness as an important, however long term development towards intelligent cargo systems (Huschebeck *et al.* (2009)). Furthermore, one of the general development directions today is towards a stronger real time monitoring of the movements of dangerous goods (Huschebeck *et al.* (2009)).

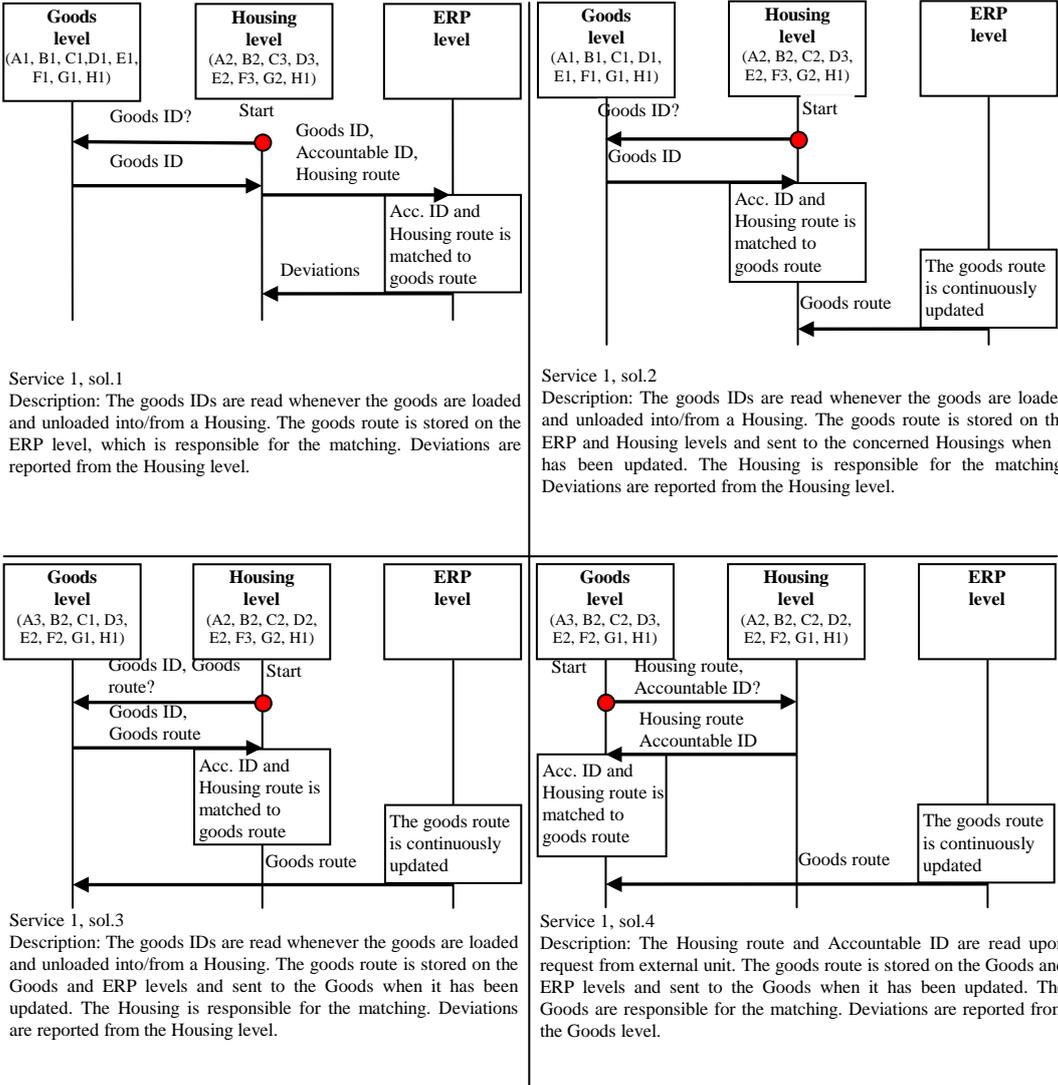
### **3. The route and priority of the goods are updated based on predicted delay, customer priority etc., and reported upon request**

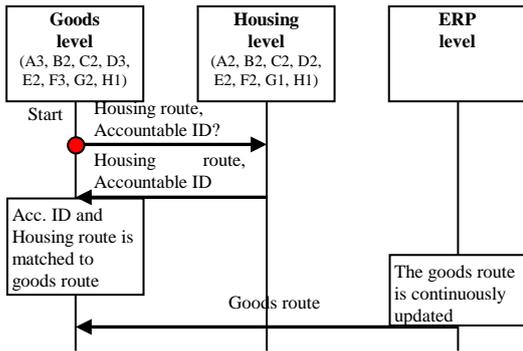
**Description:** The service updates the goods priority and route, based on the customer specific priority, delivery time window, estimated time of arrival and costs connected to, at the best, the different routes that are available between current and final position, or alternatively route probability calculations etc. Depending on implementation, the priority and route can be sent to a questioning unit from either the housings or the goods.

**Motivation:** Implementing this service on the goods represents an example of the more visionary, intelligent services that may contribute to more efficient transports (higher filling rates, improved loading/unloading procedures etc.). An intelligent goods based solution furthermore indicates a collective transport system based on time tables, governed by needs. If this solution is proved to be efficient, it represents an effective alternative to the centralized management currently used by most actors today.

In general, each service is dependent on getting the correct input information (which might be stored on different places) and to, in most cases, be able to deliver the output information to a number of receiving actors or units. A transport chain usually involves many different actors, such as consignor, consignee, driver, terminal/warehouse operator, forwarder/carrier, public authorities etc. All these actors may take part of the information reception/delivery of the

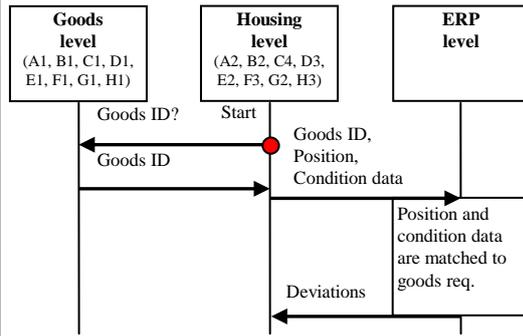
services. From our perspective however, we do not need to know exactly which actors are involved but rather where the actors receiving/delivering the information are situated. In particular, we differentiate between long and short communication. On account of this, we have simplified the transport model by concentrating on between which levels communication occurs, instead of actors or units, communicate. We have identified three such levels; Goods level, Housing level and ERP level (Jevinger *et al.* (2009)). The Housing level can be seen as a level above the Goods level, but below the ERP level. The descriptions of the architectural solutions presented in this paper are all based on these three levels, and any communication within each level has been left out. In order to identify all possible solutions for each of the three services, we have listed all combinations of capabilities on the goods and housing level, based on table 2.1 and figure 2.1. From this set of solutions, the redundant or unrealistic ones have been removed. The most relevant ones from the final set is shown in figure 3.1. The specified capabilities of the Goods level in figure 3.1 corresponds to the goods-related capability dimension presented in table 2.1, and the capabilities of the Housing level corresponds to the housing related capability dimensions in table 2.1. The capabilities of the ERP level have not been specified since the resources are considered always to be sufficient on this level.





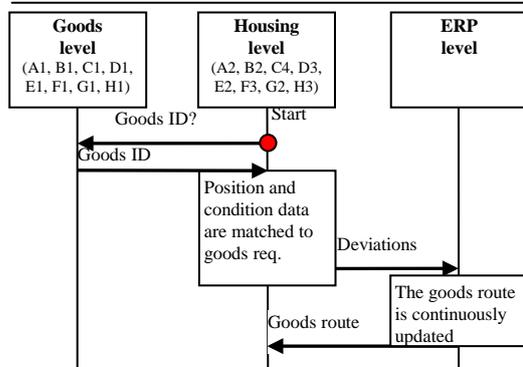
Service 1, sol.5

Description: The Housing route and Accountable ID are read autonomously whenever the goods enter or leave a Housing. The Goods are responsible for the matching. The goods route is stored on the Goods and ERP levels and sent to the Goods when it has been updated. Deviations are reported continuously from the goods to a stored address or undirected. If the Goods have G2 capability, the position can also be reported.



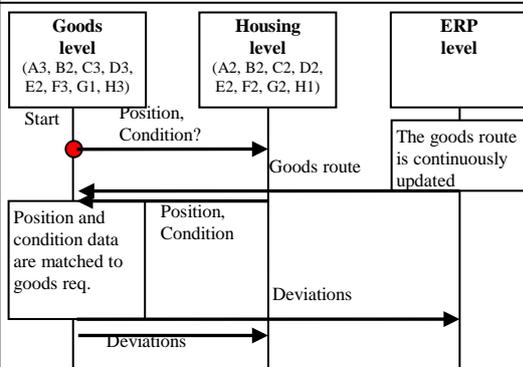
Service 2, sol.1.

Description: The goods route and the requirements on the goods conditions are stored on ERP level. The goods IDs are read and sent to ERP whenever the goods are loaded and unloaded into/from a Housing. The Housing level continuously sends condition and position data to ERP.



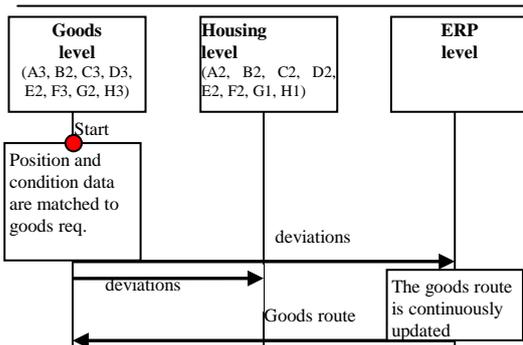
Service 2, sol.2.

Description: The goods route and the requirements on the goods conditions are stored on Housing level. The goods IDs are read whenever the goods are loaded and unloaded into/from a Housing. The Housing level sends all condition and position deviations to ERP. The goods route is also stored on the ERP levels and sent to the concerned Housings when it has been updated.



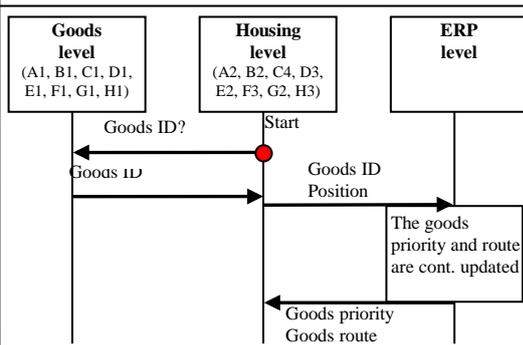
Service 2, sol.3

Description: The goods route and the requirements on the goods conditions are stored on Goods level. The Goods level continuously reads condition and position data from Housing. The Goods level sends all condition and position deviations to Housing and ERP. The goods route is also stored on the ERP levels and sent to the Goods when it has been updated.



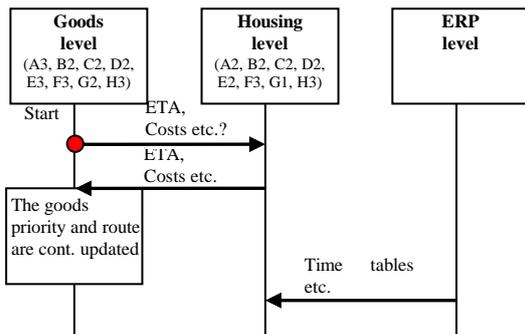
Service 2, sol.4

Description: The goods route and the requirements on the goods conditions are stored on Goods level. The Goods level has a sensor for condition and position data. The Goods level sends all condition and position deviations to Housing and ERP. The goods route is also stored on the ERP levels and sent to the Goods when it has been updated.



Service 3, sol.1.

Description: The goods route, goods priority, customer specific priority, estimated time of arrival and costs connected to different routes etc. are stored on ERP level. The goods IDs are read and sent to ERP whenever the goods are loaded and unloaded into/from a Housing. The position is sent continuously. The goods route and priority are stored on both ERP and Housing levels and sent to Housing when they have been updated.



Service 3, sol.2

Description: The goods route, goods priority, customer specific priority, estimated time of arrival and costs connected to different routes etc. are stored on Goods level. The Goods level autonomously updates the route and priority. Information needed by the Housing is continuously sent from other Housings and ERP levels.

Figure 3.1 Architectural solutions

One of the most essential parameter in the three services presented is the route, or rather the itinerary of the goods, which for each part of the transport, include information about the position of the next stop, the organization responsible for the transport link (e.g. a carrier or terminal operator) and the delivery time window to the next transport link. A transport link represents a transport from one location to another but it may also represent terminal storage before the goods are handed over to the next carrier. For instance, if a terminal operator is responsible for a transport link, the corresponding route parameter component specifies the position of the terminal, the terminal operator and the delivery time window towards the next carrier. In figure 3.1, we denote this information as Stop ID, Accountable ID and Delivery Time Window. Furthermore, we also assume that the route parameter is dynamic since we want the architectural solutions to be able to handle dynamically updated routes, even during transport. In the architecture analysis, we assume that either the ERP level is responsible for decisions about changed goods routes, or the goods make their own decisions autonomously. The route of a vehicle is denoted Housing route. If the Housing is a terminal or warehouse, the Housing route simply contains information about the position of the terminal/warehouse. Since the goods route is assumed to be dynamic during the transport, the route of a vehicle must also be dynamic.

If a service is dependent on the capabilities of a housing surrounding the goods, reloading during the transport might cause these capabilities to disappear. For instance, if they are only present in a transport container used for only a part of the transport, the services would need more than one architectural solution, or they would cease to function. Since our architecture analysis involves different solutions of the same service, using different levels of intelligence on the Goods level, the consequences of such a scenario can be estimated based on these. However, we leave this particular analysis for future work. Additionally, the different housing levels enclosing the goods on the Goods level (packet, pallet, transport container etc.) have also been excluded, since we believe that our analysis can equally be applied on a more complicated hierarchy. In (Jevinger *et al.* (2010)) a more detailed discussion of goods hierarchies are given.

The architectural solutions in figure 3.1 show that each service can be implemented in different ways. In particular, there are many alternatives of how to partition the capabilities between the Goods and Housing levels. The identified solutions can hereby be used to investigate the advantages and disadvantages with different implementations of the same

service. Moreover, each solution can also be further investigated by reducing the capabilities and thereby reducing the service functionality and possibly quality. For instance, if a solution requires position sensor data capability on the Housing level but only the Terminals/warehouses, and not the vehicles, provide support for this, the quality of the service will in some way be reduced (e.g. resulting in less frequent service output information). Finally, apart from evaluating different implementations, the architectural solutions can also be used to investigate which functionalities can be achieved with different sets of capabilities, once the initial evaluations have been performed.

#### 4. QUALITY ANALYSIS

A service may be implemented in several ways, and each implementation may have different qualities. In order to investigate these qualities, we propose a number of quality attributes, listed in table 4.1. These can be used to evaluate and compare the performance of the architectural solutions, e.g. to determine which one is best suited for a specific situation. The list of quality attributes have been identified though a theoretical analysis of which qualities aspects are most influenced by different architectural choices, i.e. what behaviour of the system is influenced given the different choices. As an example of comparison, the centralized configuration in figure 3.1, service 1, sol. 1, makes it convenient to update the goods routes from the ERP level (no wireless communication required for this). However, the reliability of response is lower in comparison to for instance the purely intelligent goods based solution in figure 3.1, service 1, sol. 5, since it will only be able to detect misplaced goods within a Housing and not the goods that are placed outside. Moreover, it requires the support of reading the Goods ID in all Housings, otherwise the reliability of response will be even lower. Implementing the intelligent goods based solution on the other hand requires a high level of processing power on the Goods level, which might be costly.

Table 4.1 Quality attributes

No	Quality attribute	Description
1	Time to response (TtR)	Time to get the response from the service, assuming the goods and the housings have the required capabilities. The value of this quality attribute may be dependent on wireless coverage, location of information entities, updating procedures etc.
2	Reliability of response (RoR)	Information reliability of the response from the service. Information from a service may be more or less complete due to changing capabilities during transport. For instance, information may be sent in real time during the whole transport, or sometimes in real time and sometimes only at terminals, depending on the capability support of the transporting vehicles.
3	Quality of response (QoR)	The level of detail of the information response from the service, assuming the goods and the housings have the required capabilities. For instance, stolen goods may be more easily tracked if a service reporting about stolen goods also would include information about the position of the goods. The level of detail of the service response would hereby be higher in relation to a response without position information.

4	Integrity (I)	Information integrity, both concerning the stored information entities and the information messages transmitted. The value of this quality attribute may be dependent on the number of intermediaries, location of information entities and how well they can be protected etc.
5	Short-range wireless communication (SW)	Amount of short-range wireless communication needed by the information transmissions.
6	Long-range wireless communication (LW)	Amount of long-range wireless communication needed by the information transmissions.
7	Goods processing power (GP)	Amount of processing power needed on the Goods level.
8	Vehicle processing power (VP)	Amount of processing power needed on the vehicles.

We will analyse the architectural solutions based on the Analytic Hierarchy Process (AHP) (Davidsson *et al.* (2006)). AHP provides an approach to select the most suitable alternative from a number of alternatives evaluated with respect to several criteria. This analysis will show a way to select the most suitable architectural solution for a particular application under specific circumstances. However, we do not have any measured data to base the analysis on and we will therefore use estimated, relative values instead. Naturally, without real data we will not be able to draw any conclusions from the results of the analysis. The purpose is simply to show how it can be performed. We have chosen to base the analysis on the four different solutions of service number two. Moreover, we will evaluate the architectural solutions with respect to the proposed quality attributes. In accordance with AHP, we have therefore assigned priorities to the quality attributes, see table 4.2. These priorities are also estimated, subjective values and the result of the analysis is influenced by these settings. The first set of priorities (P1) reflects a situation where the long-range wireless communication resources are scarce and the priority of the corresponding quality attribute is thus set to relatively high. Furthermore, a relatively short time to response and high integrity is also required. The second (P2) reflect a situation where the processing power on the goods is low.

Table 4.2 Priorities

Priority	TtR	RoR	QoR	I	SW	LW	GP	VP
P1	0.2	0.1	0.1	0.2	0	0.4	0	0
P2	0.1	0.1	0.1	0.1	0	0.1	0.4	0.1

The next step of AHP would involve collecting metrics for each of the quality attributes, for each architectural solution. Since we will perform our analysis without metrics, we will skip this step and instead use estimated, normalized values of the quality attributes, see table 4.3. These values will, in combination with the priorities above, be used for calculating an overall performance result for each architectural solution. We assume that low values of the quality attributes TtR, SW, LW, GP and VP are desirable, and therefore a high real, measured value should result in low or no contribution to the final performance result. This contribution is however also depending on the set of priorities. If for instance we do not want the priority of a low level of processing power on the goods to influence the result, e.g. if it constitute no obstacle, the corresponding priority can be set to 0 to eliminate this factor. Values of the

quality attributes RoR, QoR and I should, for similar reasons be high and thus the opposite should be true for these. In table 4.3 a relatively low value represents a less desirable quality than a higher. A low corresponding value in table 4.3 will hereby result in a relatively low contribute to the overall performance result.

*Table 4.3 Estimated, normalized values of the quality attributes for each solution of service no 2, and the results*

	TtR	RoR	QoR	I	SW	LW	PG	PV	Result P1	Result P2
Sol. 1	0.1	0.2	0.2	0.3	0.25	0	0.45	0.2	0.12	0.28
Sol. 2	0.3	0.2	0.2	0	0.25	0.4	0.45	0.1	0.26	0.30
Sol. 3	0.3	0.2	0.2	0.3	0.1	0.3	0.1	0.3	0.28	0.2
Sol. 4	0.3	0.4	0.4	0.4	0.4	0.3	0	0.4	0.34	0.22

In the final step, we will calculate the final performance result for each architectural solution. This is done by multiplying the priorities (table 4.2) with the corresponding normalized values (table 4.3), for each architectural solution. These are thereafter summed for each architectural solution and presented in the last two columns in table 4.3. As expected, when long-range communication resources are scarce, architectural solution number 4 is the most suitable and when processing power on the goods are low, solutions number 1 and 2 are superior.

## 5. CONCLUSIONS

Implementing intelligence on the local level (e.g. on the goods or housings) both enable new types of services and provide old services with new opportunities (e.g. paperless handling, positioning, condition monitoring etc). Some of these services are completely dependent on some form of local intelligence whereas others may be implemented either as entirely centralized services or utilizing decentralized intelligence, based on for instance intelligent goods. However, depending on the implementation, the services put different requirement on the level of intelligence of the goods. Moreover, the benefits from using intelligent goods vary from service to service.

This paper has illustrated how a previously published intelligent goods framework can be used to identify relevant architectural solutions for potential intelligent goods services, with different levels of intelligence on the goods. The framework has slightly been extended to fit our purposes and the method is illustrated using three specific potential intelligent goods services. The architectural solutions show that a number of alternative implementations may exist for a specific service, and different situations may require different implementations. In order to decide which solution is the best, given a particular situation, the solutions must be evaluated and compared against each other with respect to the different situations. To lay the foundation for such an analysis, the paper also proposes a set of quality attributes that are used in a qualitative analysis of one potential intelligent goods service.

The method and approach for identifying and evaluating architectural solutions for potential intelligent goods services have not been verified against implemented cases. The main reason for this is that goods examples of advanced implemented intelligent goods services are hard to

find. As future work though, we intend to test our results through simulation and/or empirical investigations.

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