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Integrated Modelling of Business Processes and Real Time Communication for Public Transport

Modelling Connection Protection with Business Process Model and Notation

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Abstract— *This paper proposes a generic communication system, which is controlled by a formalized process model. This system architecture is instantiated for the public transport domain. The operation of this system combines a distributed work-flow model (Business Process Modell and Notation, BPMN) with open communication standards incorporating real time communication (RTC) characteristics as provided by e.g. LTE mobile IP networks. The performed formalization meets the requirements of a typical scenario in public transport: connection protection. The participants involved are represented by the control center, along with the mobile and distributed users: drivers and passengers. Formalization with BPMN allows the modelling and understanding of the various interactions and communications between the different agents. For public transport operators the approach set out in this paper leads to a considerable economic advantage. Passengers benefit from improved customer experience in seamless travel across different modes of transportation.*

Keywords—*Business Process Modelling, Connection Protection, Public Transport, Open Standards, RTC, LTE*

I. MOTIVATION

One of the most crucial requirements for reliable and efficient operation of public transport is the knowledge of all incidences which take place during an operational day in real time. This information includes delays, accidents, road work, or special events. In order to facilitate decision making to perform the most favorable solution for the passengers, their needs and requirements have to be considered. To achieve this, the availability of an accurate communication between control centers and vehicles is a fundamental requirement. Current state of the art of communication technology used in the public transport domain has considerable disadvantages.

The use of *dedicated communication infrastructure* (analog mobile radio, digital mobile radio systems, special mobile infrastructures…) is economically disadvantageous [8]. The utilization of public mobile networks is desirable.

The communication technology used in public transport consists of *heterogeneous systems with proprietary interfaces*. It would be desirable to unify and standardize these systems by means of a unique and public general process language. This language should provide high level tools, capable of being integrated with the low level systems from each public transport operator. Moreover, it should facilitate the development of graphical user interfaces, easily handled by any user.

The *lack of process integration* in a proper workflow causes a considerable loss of information. The use of a suitable modelling environment allows the correct and complete representation of all process phases. In this way, the identification of the possible problems and their solution is facilitated.

In order to overcome the previously described disadvantages, integrated modelling of business processes and real time communication will be achieved on the basis of an open-standards architecture.

II. METHODICAL ENGINEERING OF DISTRIBUTED WORKFLOWS

Engineering of distributed business workflow is a complex task. Besides profound knowledge of the application domain, a coherent set of means of description for formalization, adequate tools as well as an appropriate methodical approach in terms of a sequence of steps to be performed during the design phase is required. These three elements of the methodical engineering of distributed workflows are described underneath.

A. Means of Description

For a proper operation of the system, an explicit, unambiguous, correct and complete process definition with clearly assigned roles and responsibilities is a fundamental requirement.

1) Benefits of Formalization

Process definition is facilitated by the use of formal methods in process design which has the following three advantages. (a) *Explanatory function*: simply formulating and documenting "how things are done" within an organizational framework makes a direct contribution to repeatedly deliver good service quality. Graphical notations support communication and understanding by all associated stakeholders. (b) Formalization provides additional *benefits of available analytics* (e.g. verification) which contributes to the stabilization of the processes. (c) *Disambiguation*: operator errors can be reduced and an optimal user experience even under accident conditions can be guaranteed as all eventualities are covered in the process definition.

2) Advantages of Business Process Model and Notation

Business processes can be seen as an orchestrated and repeatable pattern of business activities enabled by the systematic organization of resources into processes that provide services. Processes can be depicted as a sequence of operations and declared as work of a person or group within an organization or across organizational boundaries. Different graphical representations of work flows are available (e.g. UML activity diagrams, Event-driven process chains (EPC) as well as work flow Petri nets [9]). All of them are frameworks of token-based semantics allowing definition and automation of distributed processes. For the given application in the public transportation domain the decision was made to use the Business Process Model and Notation (BPMN).

The first reason for using BPMN is the *availability of process definition tools*. Tools with graphical user interfaces allow the definition of workflow processes in an intuitive and simple way. Furthermore the powerful analysis techniques (and simulations), which Petri net theory provides for the verification of the correctness of workflow procedures, can be used as tool chains allowing to translate BPMN to Petri nets and back [9].

The second reason for using BPMN is its *expressiveness*. BPMN supports control flow behavior as well as interaction behavior and data flow. Therewith it is not only used for processes within one company, it is also used for modelling interaction processes of multiple companies or organizations [9]. BPMN allows the formalization of distributed and interacting processes carried out by different agents. The manifoldness of interactions between them is uniquely represented by interchanged messages.

3) Notational Elements of BPMN

BPMN [2] is a standard specification developed by Business Process Management Initiative (BPMI) in 2004 [3] and subsequently maintained by Object Management Group (OMG) (merged with BPMI) since 2005 [4]. From March 2011, the current version is 2.0. BPMN models are represented by means of Business Process Diagrams (BPDs). The BPD associated to the proposed system contains the following elements:

1) *Pools:* each pool depicts one participant in the whole system, and is associated to an executable process.
2) *Tasks:* are represented with a rectangle. They represent any activity to be done. "*Send tasks*" are specific cases, which are utilized to send messages from one process to another.
3) *Exclusive gateways:* are represented with a diamond shape and a cross inside. When the process reaches a gateway, a specific condition is evaluated. The result determines the path to be followed.
4) *Events:* are represented with a circle. They mean anything that happens. In the proposed model, 3 kinds of events are used. (a) *Receive events* (symbol: envelope): a message from another participant is received. (b) *Timer events* (symbol: timer clock): the process sleeps during certain time (set by a timer), and then it continues. (c) *Signal events* (symbol: triangle): in order to initiate the execution of a sub-process, a process triggers a "throw" signal event (filled triangle), which is caught by the sub-process by means of a "catch" signal event (empty triangle).

B. Process Definition Tool

In order to support the before mentioned development process (as well as its graphical specification in BPMN) tool support is required. Usually workflow management systems include two tool aspects. (a) A *Process modelling environment* which can be used to author BPMN 2.0 compliant processes graphically using a browser. The process files are stored by the server in a database model repository. (b) A *Runtime environment* includes several components. The process engine executes BPMN processes. The model repository stores the process files on a server in a database model repository. A simple web application allows the design of human interaction (tasklist).

For research-oriented development activities it was important to use an open-source platform. For this reason a comparative analysis of different platforms (e.g. activiti and camunda) has been performed. Based on this the decision was made to use the camunda development environment for implementation of the prototype described in section III.

C. Engineering Method

The methodical approach of incremental prototyping has been chosen for the implementation of the support functions for the public transport domain. The primary goal of the project was to conduct a first feasibility study on the applicability of an open-standards design approach. With incremental prototyping the project could benefits from reduced time and costs as well as improved and increased user involvement to

get feedback on the implemented system solution. The procedure applied in the project was as follows:
(1) *Initial requirements analysis for prototype*: Basic requirements have been determined based on an intense review of the current state of the art. This includes relevant publications in journals and on conferences as well as published standards for the communication between large public transport information systems and between public transport operators [10] as well as for the communication between public transport authorities and passengers (TRIAS, Travellers Realtime Information and Advisory Standard [1], [11] and [12]).
(2) *Development of initial prototype*: The initial prototype is developed that includes a first version of user interfaces. This step is facilitated with the engineering tools applied in the project. The process design tool allows implementation of a simplistic interaction concept. This facilitates discussions with prospective users and domain experts in the next step.
(3) *Prototype review:* Domain experts, including end-users (passengers, bus drivers, dispatchers) examine the prototype and provide feedback on additions or changes.
(4) *Prototype revision and enhancement of the prototype*: Using the feedback both the specifications and the prototype can be improved. Since necessary changes discovered in the review phase (e.g. integration of state-of-the-art interfaces and architectural considerations) have been introduced steps 3 and 4 had to be performed repeatedly.
Overall this methodical approach allowed the development team to add features, or make changes that could not be conceived during the requirements and design phase.

III. Application: Connection Protection in Public Transport

In order to optimize customer experience in public transport, attention must be laid on the possible consequences of delays on connections [13]. First of all, delays often lead to an increase of travel time. Secondly, passengers can miss a transfer if a vehicle is delayed and a connecting vehicle does not wait. Connection protection manages these kinds of situations, dealing with the decision of waiting for the connecting passengers from one delayed feeder vehicle. It can provide a very important and necessary solution on the critical situations of public transport availability. These kinds of situations can be measured according to spatial factors (where services are less frequent, like in rural areas), along with temporal factors (when services are less frequent, like in evenings). However, connection protection is a complicated optimization problem, characterized by a trade-off between time losses incurred by transit passengers not leaving the receiving vehicle and connecting passengers changing from the feeding vehicle to the receiving vehicle. The following sections describe the participants in this process, the message types interchanged between the participants as well as the sub-models.

A. Participants in the Process Model

In connection protection, several agents take part (control centers, drivers and passengers), and the performed tasks by every agent need to be completely and correctly defined and differentiated. For this reason in the proposed system, a business process with seven participants is modelled [6][7]. Thus, in the further cause of this article a BPMN based collaboration diagram, composed of seven pools, is shown.

- *Participants 1 and 2*: Bus (Feeder Bus, BF / Connecting Bus, BC): Vehicles involved. Each one of them sends regular real time updates to its corresponding ITCS.
- *Participants 3 and 4*: ITCS (Feeder ITCS, IF / Connecting ITCS, IC): Intermodal Transport Control Centers. They manage the incidents for their corresponding buses.
- *Participant 5*: ITIS [IT]: Intermodal Transport Information System. It contains all information related to schedules, and responses to passenger requests.
- *Participants 6 and 7*: Passengers (Feeder Passenger, PF / Connecting Passenger, PC): They interact with the ITIS.

B. Message Types in the Process Model

Three kinds of messages are interchanged between the participants (see [1], [11] and [12]). In order to make the representation easier, a two-letter code is associated with each participant and message:
1) *Real-time update* [RT]: sent from each bus to their corresponding ITCS, it contains information about the current position and predicted arrival time.
2) *Decision* [DC]: the decision to wait, or not, for the delayed feeder bus, is taken by the ITCS connecting, and then forwarded to the other participants.
3) *Trip planning* [TP]: trip requests are sent from the passengers to ITIS. Return values from the ITIS contain all the information about a trip, such as bus lines and schedules.
In order to name the different messages, a message code is used as a unique identifier in the following way: SS_RR_MM. Where, SS represents the sender, RR the receiver, and MM the message code. For instance, the code IC_IT_DC represents a message sent from ITCS (Connecting) to ITIS, which contains a decision.

C. Submodel 1: Interaction between ITIS and Passenger

The process begins when the passengers intend to make a trip, and make a request to ITIS, which answers them with a Trip Planning (TP) message. Moreover, whenever there is a change (delay or decision to wait) in the planned time schedule, ITIS is informed, and subsequently sends a notification to the passengers involved in the affected trips.

D. *Submodel 2: Interaction between ITIS and Passenger*

The ITIS provides passengers with a choice set of connections between their origins and destinations. The ITIS determines connections with respect to different criteria such as the (scheduled) travel time and the number of transfers. In terms of an on-trip travel assistance the passenger needs a time table information which reflects current delays within the network. For this reason real-time data needs to be considered for the generation of new routes once a deviation from the initial schedule is detected. For this reason each vehicle regularly sends real time information about its position. Based on this information arrival times can be predicted. If a relevant change is detected, the ITCS forwards this information to the ITIS and to the other ITCS, which forwards a decision to wait to its corresponding vehicle. Reference is made to specific research related to the algorithmic approaches for the determination of “robust” connections (for example based on event-activity networks as outlined in [14]). Robustness in this case means that delays have a minimum impact on the practical feasibility of a specific routing.

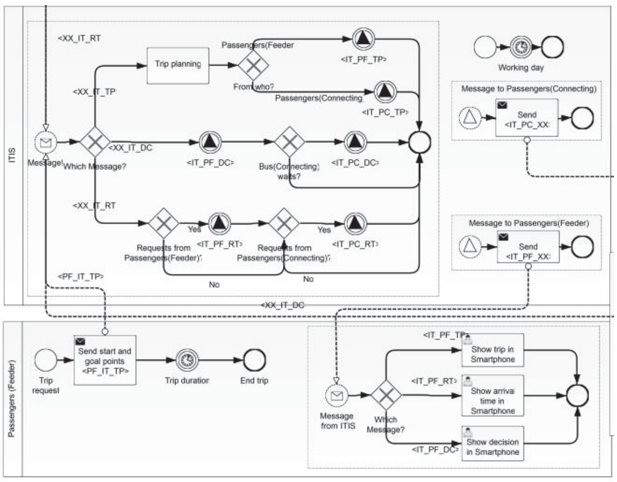

Fig. 1. Sub-Model 1: Interaction ITIS and passengers (Feeder bus)

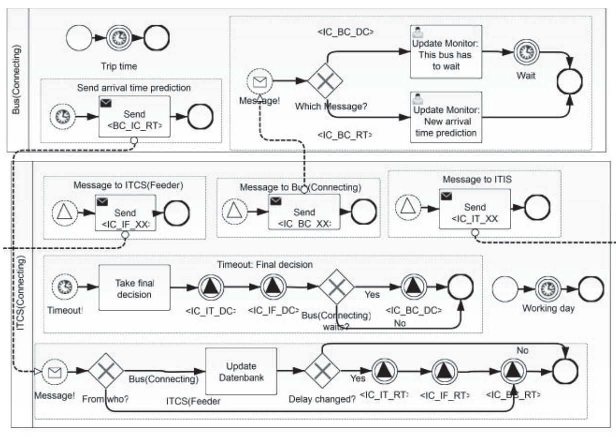

Fig. 2. Sub-Models 1 and 3: Interaction between ITCS and Bus

E. *Submodel 3: Decisionmaking*

The decision of waiting, or not, for the passengers from a delayed feeder bus is taken by the ITCS (Connecting). In the operations control center decision making is supported by suitable algorithms which compare possible time gains (of passengers in the feeder bus who wish a connection is kept) against time losses (of passengers in the feeder bus who suffer from a prolonged travel time). The use of algorithmic solutions to the connection protection problem (also referred to as delay management in a wide body of available literature [15], [16]) makes decision making transparent and facilitates communication to the passenger in case a connection cannot be kept [17]. Once a decision is made, it is forwarded to ITIS and the ITCS feeder. In case that a waiting has been decided, the connecting bus is also informed.

IV. Heterogeneous Networks – Problems and Solutions

In public transport, most of the involved agents are mobile. Therefore, they need a communication system enabling them to communicate between each other, regardless of time and location. The IP protocol is considered to be used in the future in every communication, from any kind of source (video, voice or data). Voice will be not only the most used source in communications, but also an essential part of the IT workflow. Therefore, several technical restrictions must be taken into account:

- *Real-time restrictions*: voice communication requires real-time communication (RTC) which needs to be guaranteed in IP networks.
- *Interoperability restrictions*: this is a very common problem in regional transport. The presence of different companies using IT can cause interoperability problems.
- *High variability restrictions*: the mobility can cause connection losses, along with the addition of a considerable latency in the communication.
- *Secure data transmission*: many applications in public transport require transmission of sensitive data. For example, the operational status of vehicles, verification information for electronic ticketing and voice communication between vehicles and the operations control center. Especially in open networks such as the internet it needs to be ensures that security function will not be compromised by third parties [8].

A. *Open vs. proprietary standards*

An important aspect of the proposed system is the use of open communication standards, developed by several different authorized stakeholders and standardized by organizations like IETF (Internet Engineering Taskforce), ETSI (European Telecommunication Standardization Institution), 3GPP (Third Generation Partnership Project), etc. This is a considerable advantage, due to the possibility of acquire different improvements from each single provider. Specifically, the open standards CEA (Communications Enabled Applications) and Real Time Communication (RTC) give rise to significant potential for product and process innovation - not only in the public transport domain. WebRTC is an open standard for real-time communication which is currently being standardized by the World Wide Web Consortium (W3C). It enables applications with high demands on the real-time capability (voice over IP, video streams, etc.) within a web browser. WebRTC is used for recording, coding and (peer-to-peer) real-time transmitting multimedia content between web browsers.

B. Communication System Architecture

We propose a communication system for public transport, which utilizes open standards [6][7]. For its implementation, a three component architecture is proposed, as it can be seen in Fig. 3. There are three user interfaces: bus driver user interface, control center user interface, and passenger user interface. All of them run as Web GUIs. For any mobile application, a proper RTC-enabled mobile IP-based communication (layer 3) must be established. In order to achieve a reliable communication, several factors must be taken into account (bandwidth prediction, Quality-of-Service (QoS) and secure data transmission). In order to ensure secure communication data to be transmitted needs to be encrypted and/or transmitted via virtual private networks (VPN). A virtual private network is a logical network which is closed to outsiders, which bases on layer 3 of the OSI reference model and uses tunneling mechanisms for IP-based data transmission [8].

The use of web technologies in communication architectures allows the development of multiple operative models, such as "cloud computing" or "Software as a service". By means of the use of these resources, the public transport operators can save on certain costs of acquisition and operation, since they can delegate these activities to external IT providers. In the medium term, all the mobile IP communication will be deployed by means of broad bandwidth LTE networks. Mobile Virtual Network Operators (MVNO), which do not own their physical networks but rent them from MNOs (Mobile Network Operators), offer certain typical services, such as group calls [5]. Moreover, on the dedicated IP connections, the prioritization services can be offered, along with the Quality-of-Service parameters. It is necessary to develop migration scenarios during a transition period, in which the integrate use with conventional radio networks (both digital and analog) can be possible. For this reason, several restrictions must be taken into account, such as the option of "non-IP connection" in Legacy Mobile Networks (Fig. 3).

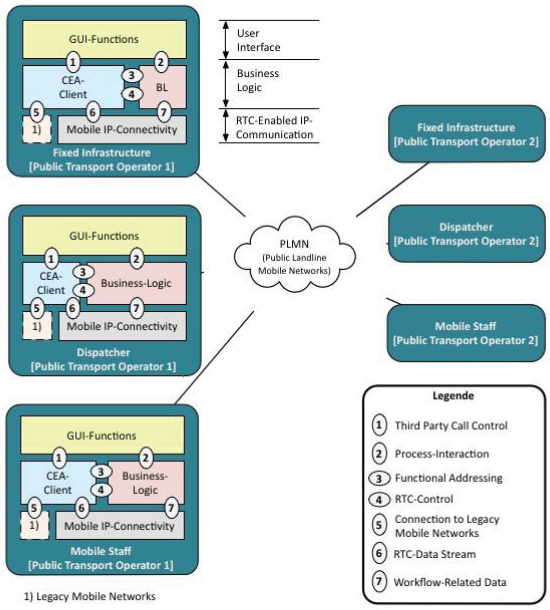

Fig. 3. Communication system architecture

Figure 4 illustrates a simple example of CEA interaction controlled by the BPMN based Business-Logic according to the communication system architecture (Fig. 3). Depending on user interactions in Phase 2 the BPMN CEA Task will initiate a two- or multi-leg RTC Session with VoIP and video communication between human agents being relevant in the respective process context. Functional numbering/addressing will ensure, that the business-logic can address relevant roles (e.g. the maintenance responsible for a certain type of bus), whilst the call is actually routed to the person being in charge for that role at the given time. This concept of functional numbering is similar to respective specifications of EIRENE (European Integrated Railway Radio Enhanced Network) [18].

Modern Voice-over-IP (VoIP) and Multimedia RTC-server like SipXecs (SIP X Enterprise Communication Server) implementing the concept of an high-availability SSOA (SIP Service Oriented Architecture) enable complete standardized third-party session control through the REST Webtechnology (Representational State Transfer) [19].

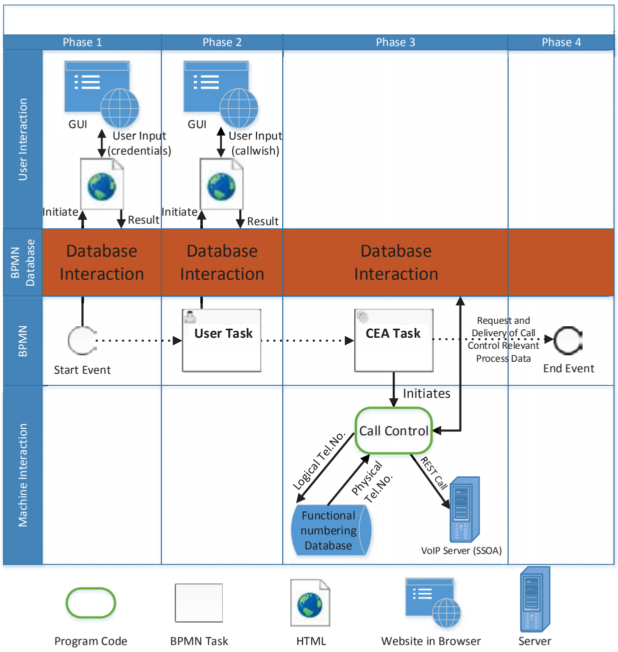

Fig. 4. BPMN controlled CEA Interaction

V. CONCLUSIONS AND FUTURE WORKS

This paper describes formal business process modelling for public transport business processes fully integrating with communication services for a highly distributed environment. The system has been developed by means of open standards, such as RTC and CEA, and formalized using BPMN. This formalization allows a clear design and understanding in order to translate the process design into an executable system. Documentation of a formalized but nevertheless understandable process model facilitated discussions with stakeholders allowing them to contribute their process knowledge in the specification phase. Further work should focus on formal verification in order to ensure completeness and correctness of the modelled processes.

The communication is performed using open standards and the IP protocol, which supposes an advantage for the use of this system on the field of Internet-Of-Things. Through the development of "Internet-of-Things" there are more and more devices that can be on-line accessed, which supposes a great opportunity for its use in the public transport field. For instance, in the project IP-KOM-ÖV [1] an IP based communication service for public transport is deployed. However, a proper integration with the application level is missing. This is precisely solved in the proposed system by using a modeling with BPMN.

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