Abstract — In this paper we present the important role of the Specification and Description Language (SDL) in the area of Telecommunications. Quality of processes such as specification and development of communication protocols and systems is highly dependent on formal description techniques (SDL). We provide detailed overview of SDL and its application in communication protocol specification. Furthermore, a new concept for performance evaluation of protocols using SDL is introduced. It is conducted on concrete modern wireless communication protocols. Additionally we discuss impact of SDL on telecommunication industry by introducing performance assessment in the early phases of communication systems development process.

Keywords — communication system engineering, performance evaluation, protocol specification, SDL.

I. INTRODUCTION

In the area of telecommunications, design and development of high quality communication protocols and communication systems is hard. Developers need to have great experience in protocol and system design, validation, implementation, optimization and maintenance. Furthermore, protocols and systems need to be comprehensively designed and functionally tested before an attempt to determine its performance is made. The afterwards redesign is costly and may cause late protocol and system delivery. There are many examples in telecommunication industry when poor system design and performance caused major project failure.

Specification and Description Language (SDL) have played a dominate role in the area of development telecommunication systems and protocols. It is a language standardized by the ITU [1]. SDL is a formal description technique wildly used when specifying most complex parts of communication protocols. Even more, it supplies an object-oriented concept for behavior description which directly has improved many communication systems and SDL-based applications [2]. Using SDL we came up with a state-of-the-art protocol performance evaluation method. We utilized this new concept in performance assessment process of IEEE 802.11 (Wi-Fi) [3] and IEEE 802.15 (Bluetooth) protocols.

The remainder of this paper is organized as follows: Section II describes SDL basic concepts, principles and benefits; Section III presents the role of SDL in communication protocol specification; and in Section IV our new method for performance evaluation of communication protocols is conducted on IEEE 802.15.1 (Bluetooth) - based system. The paper is concluded in Section V.

II. SDL OVERVIEW

SDL supports specification of protocols and systems on an abstract level. Besides its syntax, SDL’s dynamic semantics is formally defined and standardized [4]. This language is developed towards graphical representation of the specifications [5]. Its modular approach and clear distinction between behavior and structural concepts are its most powerful features. Furthermore, the inclusion of ASN.1 [6] and C-type packages completes the overall standpoint. SDL is standardized by ITU-T Standardization Sector and through years have had several major updates. Now it is capable of specifying complex, reactive, event-driven, real-time and heterogeneous systems and applications involving many concurrent processes that communicate with each other by using signals.

In the following, we overview the major concepts used by SDL.

A. Structural Concept

SDL copes with the complexity of systems by using hierarchical decomposition [7]. Besides the means of mentally dealing with complexity, hierarchical structuring provides reusability of the created components.

The SDL structure comprises of four levels: system, block, process, and procedure [8]. Processes and procedures include main behavior concept in SDL and are described later.

The system level includes a set of instances (blocks, processes, services). The blocks are interconnected by using channels. Channels are used for connecting the system with its environment, as well. Channels and signals are described later, as SDL communication concept.

Blocks are static entities in SDL hierarchy. A block can be a container for either a set of processes (more often), or for a set of block substructures. Purpose of a block is simply to combine the behavior of its processes. It does...
not influence the behavior of the specification. Processes inside the blocks communicate by so-called signal routes. Channels and signal routes are connected by connection points, which enables exchange of signals among SDL hierarchical levels.

B. Behavior Concept

Processes are the crucial entities in SDL hierarchy. They are the major components for specifying the behavior of the protocol entities and systems. Processes describe the behavior in terms of Extended Communicating Finite State Machines (ECFSM). A process executes from start transition to its first state and waits the reception of a signal trigger before transiting into next state. Between states actions may be executed, e.g. actions of assignment values to variables, sending signals, calling procedures, creating new instances. Several process instances that represent a SDL described process can exist at the same time.

C. Communication Concept

Communication is performed by means of asynchronous exchange of signals. Sending signals is only possible along the defined channels and signal routes. Signal routes are always non-delaying, while channels may delay the signals. The sending and receiving processes are not synchronized when exchanging signals. The later one keeps signals in FIFO queue until it is prepared to handle it. Process Identifiers (PIDs) are used to send signals among instances of a single SDL described process.

D. Data concept

SDL data concept is based on predefined and abstract data types. In SDL data types are called sorts. Predefined sorts are: integers, reals, booleans, characters, strings, etc. On the other hand, SDL supports generating complex data sorts. It specifies a set of values, a set of operations allowed, and a set of equations that the operations must perform.

Another approach to specify data in SDL is the Abstract Syntax Notation One (ASN.1). It is a standardized mechanism for specifying data types. ASN.1 data types can be integrated in SDL according to Z.105 ITU-T standard [9].

Most of the SDL concepts (structural, behavior and communication) are depicted in Figure 1.

III. COMMUNICATION PROTOCOL SPECIFICATION WITH SDL

The specification of communication protocols is very important because it allows the preparation of abstract models of the protocols for further analysis and testing [10]. In the following, major aspects of protocol specification are presented.

- Communication services. Specification of communication services describes the interconnection interfaces and the exchanging service primitives of the protocol. Usually each protocol layer provides appropriate services to the adjacent (upper) layers. In SDL service primitives are presented by signals and its parameters.

- Protocol entity. It is a process that describes the behavior of the protocol regarding relations to its peer entities. SDL invokes ECFSM for entities specification. Protocol entity entails corresponding protocol services.

- Channel specification. Channels are communication paths. FSMs inside protocol entities are connected thru lossless or lossy channels. If we want a channel that emulates characteristics of real radio channel, than we have to create a new system with blocks and processes which specifies the behavior of such RF channels.

Obviously SDL provides comprehensive means of communication protocol engineering. It even deals with the increasing complexity of modern wireless and mobile access protocols. There are many examples of communication systems or at least parts of it, which complex behavior is specified and described using SDL (GSM second generation of mobile systems, UMTS third generation mobile telephony systems, IEEE 802.11 Wireless Local Area Networks, IEEE 802.15 Personal Area Networks, Terrestrial Trunked Radio - TETRA networks, Digital Enhanced Cordless Telecommunications DECT systems, etc.).

IV. PERFORMANCE EVALUATION OF PROTOCOLS USING SDL

Major area of interest for any protocol analysis procedure is assessment of its performance. In [11] is presented an example of protocol performance evaluation of IEEE 802.11 based system using SDL. Here we provide another case of protocol performance evaluation using our new SDL based method.

Bluetooth bearer protocol performance is examined in presence of web traffic as an upper protocol condition. Throughput, as the most competitive protocol performance indicator, is evaluated through many simulation scenarios.

Fig. 1. Structural and behavior description in SDL
For performing the simulations, SDL simulation tool is used [12].

IEEE 802.15 Working Group for Wireless Personal Area Networks (WPAN™) brought IEEE P802.15.1 Annex B Standard in 2001 [13]. It is a SDL source written using SDL 88. This SDL model describes only the protocol behavior and abstract data structure. It is called Bluetooth behavior model. In order to assess real Bluetooth protocol performance it is necessary to build so called performance model. SDL performance model emulates real Bluetooth scenario of communicating devices.

It is standalone model that embeds obtainable behavior model and canalizes it preciseness into accurate event driven type of simulator. Assimilation and upgrade of behavior model into performance model is depicted in Figure 2.

Unlike the behavior model where only single stimuli-response pair is evaluated, the performance model introduces new entities necessary for complete communicating scenario emulation, both on system and block level. On the system level besides multiple instances of the modified behavior Bluetooth model, simulation control-block and channel-block are introduced. First one controls generation of block instances and simulation time, and the second one ensure exchange of the RF packets among Bluetooth entities.

In the foundation of Bluetooth-block lays BT behavior model. It is necessarily modified (upgraded) so it conducts its expected role of real Bluetooth device emulation. Many new processes are introduced with different purpose: for control of primitive exchange, for queuing of signals, for segmentation and reassemble, for simulation time adaptation (timers and clocks), and all these according to textual part of protocol specification.

After building the performance model using SDL Graphical Representation (SDL-GR), abstract Data Types (ADTs) are added in order to introduce important functionalities (e.g. reading and writing to file, different kinds of random number generators, etc.). Analyzer runs this model for detecting all ambiguities. Next step is conversion of the built model into a Phrasal Representation of SDL (SDL-PR). Using SDL-PR code generator produces C source code, compiles it and links it with appropriate libraries. The result of these steps is a standalone simulator executable which requires as an input...
only configuration files, needed for desired network scenario description (Figure 3). Usually each simulation scenario involves procedures of inquiry, paging, LMP connection, authentication, L2CAP connection, traffic exchange, disconnection [14]. SDL provides complete Message Sequence Chart (MSC) [15] for all these procedures, as a way of proper working validation.

![Fig. 3. Creation of the performance simulator](image)

Thru simulations we can assess protocol performance (e.g. achieved throughput) in certain scenario condition, as depicted in Figure 4. Here we change the values of Traffic Load Factor (L) which results in varying of the Bluetooth protocol performance.

![Fig. 4. Influence of the Traffic Load Factor](image)

This new method of specification analysis can be easily performed for any other kind of traffic or other communication standard.

V. CONCLUSION

Protocol and system development process is a complex one. It comprises of few phases such as analysis, design, implementation and integration. Here we clarified that by introducing Specification and Description Language, performance evaluation engineering activities can by carry out in early development phases. Communication systems are under strong constraints such as low size and power consumption, interoperability, short-time-to-market, low cost. Very often poor design of such systems results in performance problem. If there are no formal languages such as SDL, then design errors will remain concealed until system testing. This causes enormous additional costs in telecommunication industry (typical increase of the cost is by a factor 1000 for fixing the problem after product delivery) [16, 17].

On the other hand, SDL as a Formal Descriptive Tool, provides functional and performance evaluation of created protocols or systems in a more abstract phases of development. This results in high quality and efficient protocols and communication systems.

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