Components Specification for Modeling Wireless IEEE 802.11 Networks

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Abstract: - This paper presents the specification of software components intended to aid the construction of simulation tools used for modeling and evaluating the performance of computer network systems. The components specification conforms to IEEE 802.11 wireless standard. The specification focuses on relevant resources for both analysis and project phases. The components represent the elements for ad hoc and multi-cell structures. The developer of simulation tools may easily reuse this specification and implement software components using any programming language.

Keywords: - digital simulation, wireless, IEEE 802.11 standard, components, reusability, software specification.

1 Introduction

Digital simulation is frequently used for modeling and evaluating computer networks systems. In effect, the continuous evolution of computer network technologies is, among other factors, the main reason demanding new studies and continuous research on performance evaluation and, beyond that, requiring the development of new tools.

The development of simulation tools to model and evaluate computer networks systems may represent a complex task. This complexity is, in general, due to the amount of resources that must be considered and, besides that, due to the dynamic relationship among these resources.

Reusable software components [1] are resources that could be used to facilitate the implementation of simulation tools. According to Landin [2], during the development process of any software product, the analysis phase (problem description) and the design phase (solution description) are the most important ones and, besides that, these phases are time consuming.

This paper presents components specification to aid the construction of simulation tools for modeling and evaluating wireless local networks based on the IEEE 802.11 standard. Larman's development process [3] is used for the specification encompassing analysis and design phases. The development process uses Unified Modeling Language. The object-oriented approach used in this process eases the construction of components, following the principles established by Jones [4].

The software components presented in this paper represent the essential elements for modeling wireless networks using both ad hoc and multi-cell structures. These essential elements are: traffic source, sender and receiver stations, medium access control, link, access points and distribution system.

This paper is organized as follows: section 2 presents a brief introduction to wireless networking technologies; section 3 and 4 introduce the software development, focusing on the analysis and design phases; section 5 presents some conclusions.

2 IEEE 802.3 Networks

Wireless local area networks are typically considered extensions of the wired networks. In this scenario, wireless networks use radio, infrared or laser components to send frames to either wireless access points or special points that are connected to wired networks. These special points execute a type of bridging functionality [5].

The "Wireless Local-Area Networks Standard Group" is an IEEE (Institute of Electrical and Electronics Engineers) standard committee developing both the physical level specification (currently using radio or infrared) and the medium access control protocol. The IEEE 802.11 standard is the current result of this committee activity and, in terms of trends, is broadly used by many products and solutions for wireless communication.

The IEEE 802.11 standard is continuously evolving [6]. Currently, IEEE 802.11 supports high transmission rates, ranging from 1 and 2 Mbps to 5 and 11 Mbps. Besides that, a new version of IEEE 802.11, the 802.11b, is under development supporting transmission rates up to 45 Mbps [7]. This will represent a quite interesting evolution of the technology with many target applications.

The IEEE 802.11 defines the architecture for wireless networking as based on cells. These cells are called BSA (Basic Service Area). BSA size (physical size)

depends on environmental characteristics and transmitters / receivers power capacity. Other important basic definitions used in wireless networking architecture are [8]:

- BSS (Basic Service Set) – BSS represents a group of stations communicating in a cell.
- AP (Access Point) – APs are special stations responsible for the capture of frames originated in one cell and having as the destination, stations in other cells. These outflow cells are sent through a distribution system.
- DS (Distribution System) – DS represents a communication infrastructure connecting multiple cells in order to spawn network coverage. The distribution system may use wired networking technologies.

Wireless networks, as defined in IEEE 802.11 standard, may assume **ad hoc** or **multi-cell** structures. In ad hoc wireless networks, stations communicate in a single cell, denominated IBSS (Independent Basic Service Set). In this case, stations communicate without any wired infrastructure or access point [5], as illustrated in figure 2.1.

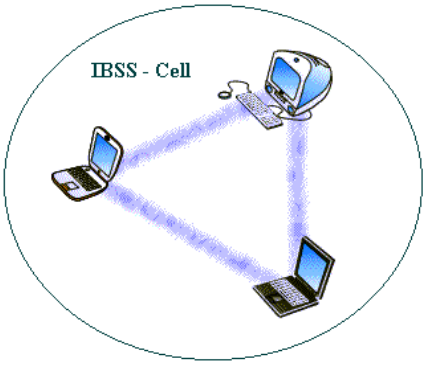

Figure 2.1 – Ad Hoc IEEE 802.11 network

In multi-cell wireless structures, the interconnection of different cells is required (Fig. 2.2). The infrastructure of interconnection corresponds to the access points (APs) and the distribution system (DS) interconnecting the APs. The distribution system also provides the infrastructure to interconnect the wireless network to other networks [5].

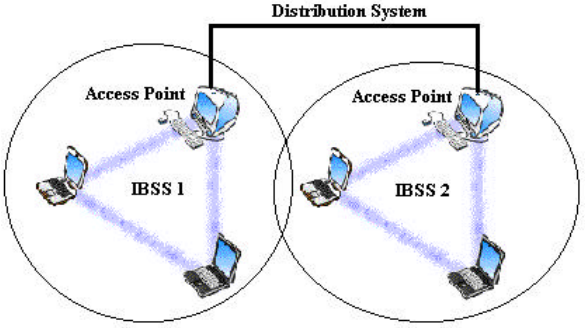

Figure 2.2 – Multi-cell IEEE 802.11 wireless network

3 Developing Process

Software components specification, or components in short, was based on the development process as proposed by Larman [3]. This approach facilitates the construction of IEEE 802.11 components as far as these components follow the object-oriented approach. In particular, this paper focuses on the analysis and design phases. Following the identification of requirements and the resources explored in each phase are presented:

- Analysis Phase: problem domain analysis using "use case diagrams", conceptual modeling and sequence diagrams.
- Design Phase: collaboration diagrams and detailed project.

4 IEEE 802.11 Components Specification

4.1 System Requirements

All the functionalities defined for the system were considered when identifying the system requirements. The system requirements are, among others, the following:

- The users of the system are developers of simulation tools.
- The proposed components reutilization is intended to facilitate the development of new simulation tools.
- Components reutilization may also be used to extend actual functionalities found in existing computer network simulation tools and, in particular, extend the functionality of those tools specialized in 802.11 technology simulation.

4.2 Analysis Phase

4.2.1 Use Case Diagram

The "Use Case Diagrams" are software artifacts used to explore and document functional requirements. The diagram in figure 4.1 illustrates a user (simulation tool developer) interacting with existing functionalities in a simulation system. This diagram eases the understanding of the system where the wireless components are inserted.

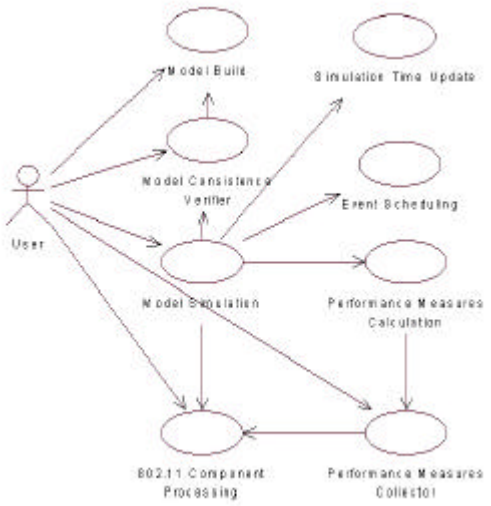

Figure 4.1 – Simulation system use case diagram

4.2.2 Concept Diagram

The concept diagram illustrated in figure 4.2 illustrates the main concepts (the components candidates in this phase) needed to promote the simulation of the wireless technology.

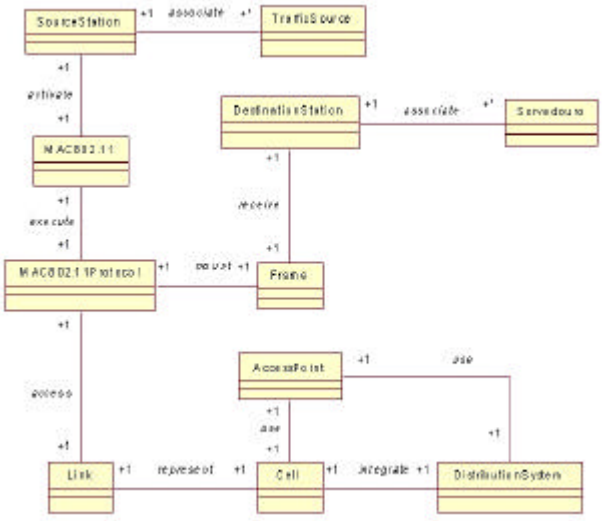

Figure 4.2 – Concept diagram for 802.11 components

4.2.3 Sequence Diagrams

The sequence diagrams are documents constructed from the use case diagrams. Sequence diagrams illustrate the functioning dynamics for the simulation system and, besides that, show how software artifacts, candidate to 802.11 components, interact with others simulation systems software artifacts using events. The sequence diagrams in figures 4.3 and 4.4 illustrate an **ad hoc** network without any collision occurrence and with collision occurrence respectively. The *Simulator* software artifact showed in these figures belongs to the simulation system.

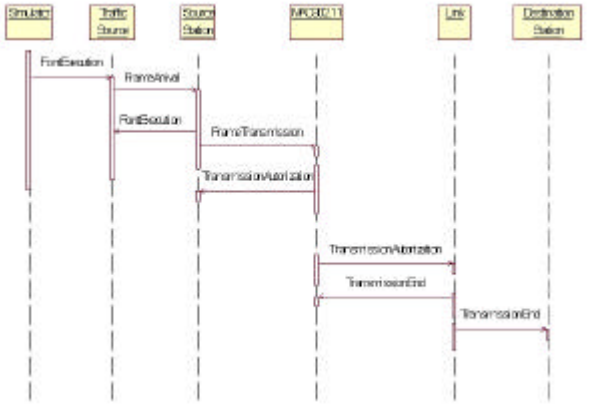

Figure 4.3 – Sequence diagram for ad hoc network without collision

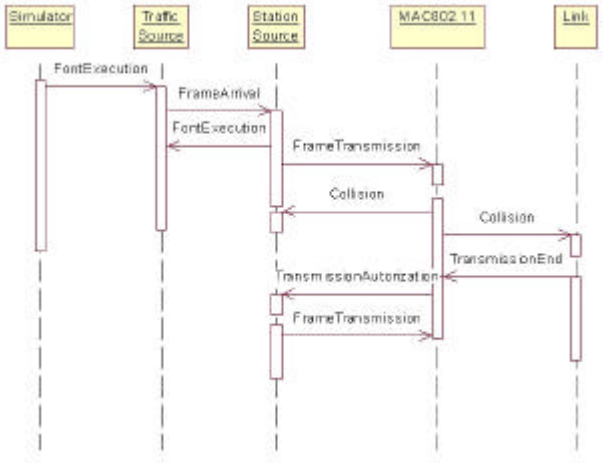

Figure 4.4 – Sequence diagram for ad hoc network with collision

The sequence diagram in figure 4.5 illustrates simulation events for a multi-cell network.

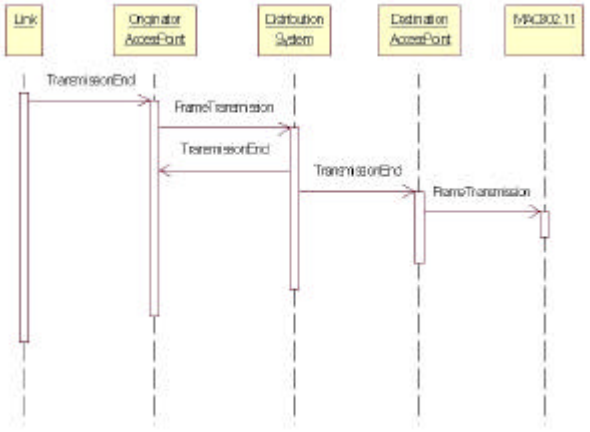

Figure 4.5 – Sequence diagram for a multi-cell network

4.3 Design Phase

In design phase the components were identified. These components represent the essential elements of the network, such as: traffic source (*TrafficSource*), sender station originating the message (*SourceStation*), protocol used (*MAC802.11*), link used (*Link*), destination station (*DestinationStation*), access point used by the sender (*OriginatorAccessPoint*), distribution system (*Distribution System*) and, finally, access point for the destination cell (*Destination AccessPoint*).

4.3.1 Collaboration Diagrams

Collaboration diagrams illustrate the system behavior by representing its components collaboration in order to comply with system functionalities. This collaboration indicates how components interact among them through the occurrence of events.

The collaboration diagrams for both ad hoc and multi-cell networks are presented in Vasconcelos [11]. The collaboration diagram *Model Configuration* is presented in figure 4.6 in order to illustrate its usage principle. The diagram shows the modeling elements for a wireless network (ad hoc and multi-cell network), represented by the component *Model*, are recognized by the simulation system.

This diagram indicates the events occurring which are necessary to both insert and remove an 802.11 component. The component *Register* has the function to register model components. This allows the simulation system to recognize components and, in this way, components are activated in order to generate events to the simulation system [10]. The components *Register*, *SystemInterface* and *Simulator* belong to the simulation system where the 802.11 components are inserted. Additional information about these components may be found in Rocha [10].

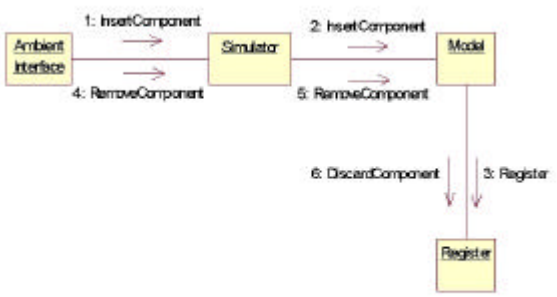

Figure 4.6 – Collaboration diagram (*SystemInterface*)

4.3.2 Detailed design

The detailed design, also referred as low-level architectural design, focuses on the individual objects and their interactions. The principle is such that it tries to solve the problem of attributing responsibilities to classes [3].

In this design, we illustrate the software artifacts (classes, interfaces), with their attributes and operations for 802.11 components. The figure 4.7 shows, as an example, the component *MAC802.11* main attributes and operations.

Figure 4.7 – Component *MAC802.11*

It follows the description of the main attributes and operations for *MAC802.11* component:

- *ID* – identifies the *MAC802.11* component.
- *Link-ID*: identifies the *Link* component used by *MAC802.11* component for frame transmission.
- *SourceStation-ID*: identifies the *SourceStation* component that requested a frame transmission. In the general model many *SourceStation* components may request frame transmission to the *MAC802.11* component at the same time.
- *DestinationStation-ID*: identifies the *DestinationStation* component that will receive the frame.
- *FrameTrannsmission*: the operation used to transmit a frame through the component *Link*.
- *EndTransmission*: the operation used to inform transmission frame occurrence to the *MAC802.11* component.

The following table presents a short description of each component representing elements for a 802.11 network. The events associated with each individual component are also indicated.

Table 4.1 – 802.11 components

802.11 Component	Description
TrafficSource	Component responsible for traffic generation. This component is activated by the event *FontExecution* and generates the event *FrameArrival. This event* must trigger the component *SourceStation*.
SourceStation	This component is responsible for triggering the component *MAC802.11* by generating the event *FrameTransmission* for frame transmission through the network. It is triggered by the event *FrameArival.*
MAC802.11	Triggered by the event *FrameTransmission*, this component is responsible for triggering the component *Link* for frame transmission. The component *MAC802.11* analyses the state of component *Link* (busy or free) and the request for frame transmission from component *SourceStation* (event *FrameArrival*). The component *MAC802.11* may generate the following events: • *TransmissionAutorization:* for the components *SourceStation* and *Link*, in order to send a frame for a single *SourceStation* transmission requests • *Collision:* for *SourceStation* components sending frames simultaneously and, for the component *Link*, indicating collision occurrence. The state of *Link* component changes to occupied.
Link	This component may be triggered by the events *Collision* and *TransmissionAutorization*, accordingly with the state condition analyzed by the *MAC820.11* component. The component *Link* generates the event *TransmissionEnd* that triggers the component *DestinationStation*/ *OriginatingAccessPoint*, indicating end of transmission for a frame in both ad hoc and multi-cell structures.
DestinationStation	Triggered by the event *TransmissionEnd*, this component is responsible for triggering the component *DestinationStation* by using event *FrameArrival* in order to deliver a frame to its destination.
OriginatingAcccesPoint	For multi-cell networks the event *TransmissionEnd*, generated by component *Link*, triggers the component *OriginatingAccessPoint*. This last component generates the event *FrameTransmission* that triggers the component *DistributionSystem* for frame transmission to stations in other cells.
DistributionSystem	Triggered by the event *FrameTransmission*, this component is responsible for triggering the *DestinationAccessPoint* component. This is realized by the event *TransmissionEnd*, for receiving a frame.
DestinatiuonAccessPoint	Triggered by the event *TransmissionEnd*, this component behaves in the same way as component *SourceStation*. When receiving the event *FrameArrival*, generates the event *FrameTransmission* that triggers the component *MAC802.11* for frame transmission, now in the destination cell.

5 Conclusion

The specification of functional elements presented in this paper, is intended to facilitate the implementation of simulation tools by adopting software reusability.

The specification presented has as its main objective to provide reusable software components used to implement simulation tools supporting IEEE 802.11 wireless technology. The components discussed are essential modeling elements for both ad hoc and multi-cell structures in 802.11 standard.

The specification followed a development process that explores in more detail both the analysis and project phases. In this way, the simulation tool developer may easily reuse the specification and implement the discussed components in any programming language at his choice.

A visual application composition tool could manipulate the components presented in this work, in order to create the simulation tool required. Future work will be directed to the implementation of the specified components in a simulation platform.

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