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Multi-hop Wireless Network Modelling Using OMNET++ Simulator

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Abstract—**The multi-hop networking plays an important role in wireless coverage area and cost reduction. In this paper, we have presented our experience to design the multi-hop wireless network and explained the realistic behavior using OMNET++ simulator. The simulation is based on proper selection of wireless node, routing protocol and other important parameters. This paper presents a detailed analysis about how INET framework can be used to simulate multi-hop wireless network. We also discussed the important modules and methodology to define simulation parameters and analyze the results for the simple scenario of multi-hop wireless network.**

Keywords—Multi-Hop, Wireless Network, OMNET++, INET, Simulation.

I. Introduction

Mobile Ad-hoc Network (MANET) extends the coverage area of the network and improves the connectivity. In this architecture, wireless network can be deployed in an area where there is no communication infrastructure. Moreover, multi-hop networks can increase the robustness of the network by transmitting packets over several paths [1]. Multi-hop wireless network can generally be used in many applications including disaster management system, vehicular networking and battle field communication [2]. Due to its several advantages, much research have been conducted in this field. To allocate the suitable multipath from transmitter to destination, a number of MANET routing based protocol have been defined e.g., DSR, AODV, OLSR, DYMO, DSDV [3]. On the transport layer, the TCP must be supported in multi-hop wireless network. Error control and congestion control mechanism must be working efficiently in order to implement multi-hopping. During error and congestion control process, the contention and control packets overheads must be kept minimize. Several application scenarios have been introduced during the last few years. Recently, with the advancement in wireless mesh network (WMN) have allowed the broadband network to expand their coverage with less cable infrastructure cost [4]. The multi-hop nature of the network also introduces the complexity and design constraints. To analyze and demonstrate the behavior of a multi-hop network before deployment, a simulation tool is a helpful mechanism to evaluate the performance. The simulation results are equivalent to the expected real scenarios.

In this paper, the design to simulate wireless multi-hop network by using OMNET++ have been explained with realistic explanation and theoretic concepts. The paper presents the detailed step by step explanation of design parameters require to design multi-hop network and provides brief knowledge about performance analysis.

Motivation: The simulation tool OMNET++ has gained much popularity for network designing. To simulate the multi-hop network in OMNET++, there is not much work available in the literature. This motivates us to share and add the knowledge of wireless multi-hop simulation using OMNET++ with new researchers.

Contribution: In this paper we explained the procedure and methodology to simulate and analyze the procedure of wireless multi-hop network using OMNET++. We also explained how available models can be used to design a network. The design parameters and simulation framework (INET) for multi-hopping simulation has been introduced. We believe, it would be very helpful and informative for new researcher.

Organization: The reminder of the paper is organized as follow. Section II explains the multi-hop wireless network, the OMNET++ simulation tool and framework require for multi-hop designing. Section III illustrates the multi-hop wireless network model, required modules, protocols and parameters for simulation. Section IV highlights the simulation outcomes and results analysis of our work. The last section V concludes the paper.

II. The OMNET++ Simulation Tool And Framework For Multi-hop Designing

A wireless local area network (WLAN) consists of two entities: Access Point (AP) and clients. The set of clients that are within the communication range of AP forms a base service set (BSS) for that AP. The backbone distribution system (DS) connects all the APs. The BSS with DS form the Extended Service Set (ESS). For multi-hop networking, the ESS mesh has been introduced in ad-hoc routing protocol [5]. MAC driver is also improved to increase the efficiency of Multi-hopping. In multi-hop, nodes do not require centralized control mechanism. A communication can be done in a distributed manner using wireless channel. The nodes that are not within the communication range of each other can transfer packets using several intermediate nodes that are also referring to as a relay nodes. In this way, the transmission power and thus interference effect can be minimized. It also helps in utilizing the frequency bands efficiently [6].

OMNET++ is an open source component based simulation tool coded in C++ language [7][8]. Different contributors have written many models for it. It consists of the following components that make up OMNET++ simulation.

- **Network:** It defines the object and contains module, sub-modules and compound modules. These modules

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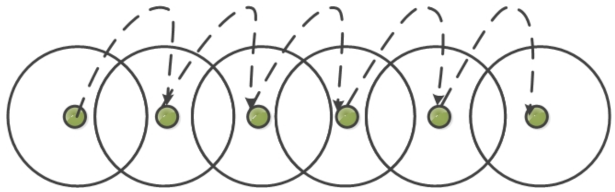

Fig. 1: A 6-nodes Wireless Multi-hop Network

communicate with each other using channel.

- **NED language:** It is a network description language (NED) used to create network topology. A user can create network topology either graphically or by NED.
- **Configuration file:** It defines how the simulation will run. In every model, it is called *omnetpp.ini*. The code in *omnetpp.ini* can be divided into two parts. One specifies the parameters and other defines the module that run the complex model functionality.

There are many framework packages for OMNET++ available freely online. You can choose one of them depending on the type of network. For example OMNET++ provides simulation models for wireless sensor networks, GPS network, ad-hoc network and many others. In our paper, we are focusing on model called INET which is intended to model the wireless multi-hop network.

INET: It focuses on modelling TCP, UDP and IP network. It provides the modelling of IPv4, IPv6, 802.11 based protocols, Ethernet and PPP. One of the sub models in this framework is manetrouting which provides the modelling of multi-hop ad-hoc network. In this paper, we are focusing on this model to simulate multi-hop routing protocol.

III. Multi-hop Wireless Network Model

To establish a multi-hop model, we used INET simulation framework. INET allows analyzing the network characteristics and hardware modelling. The InetManet framework is an enhanced version of INET which provides a tool that is necessary for ad-hoc network routing protocol simulation [9][10].

A. System Model

We used OMNET++ version 4.3.1 and INET framework version 2.2.0 for our network simulation. For multi-hopping, we used the fixed node named *adhocHost*. We used multiple channels with multiple radios for the communication between nodes. We can also implement using single channel with single radio but it produces interference and delay in the network. The network consists of 6 wireless nodes.

B. OMNeT++ Project Design

For wireless network and multi-hop wireless network modelling simulation in OMNET++, an open source communication framework known as INET is used. One fork of the INET is InetManet. It is the extension of INET that supports AODV, DSR, OLSR, DYMO and other ad-hoc routing protocols [11]. Using this framework, the feature of multi-hop routing protocol, wireless propagation model, mobility and channel assignment can be demonstrated extensively. The code in OMNET++ is written in C++ language. However, it also allows user to use higher building blocks for network designing. The simulation library represents various components that we used to design a network. These component models could be channels, objects and module parameters. The message and the packets are given by the cMessage class and its subclass cPacket. To exchange a packtes, a protocol layer uses a module. However, a packet requires additional information for a communication between protocol layers. In OMNET++, this additional information is represented by control information. In wireless transmission, the channel controller module keeps track of the nodes range and their operating frequencies. The packets are encapsulated

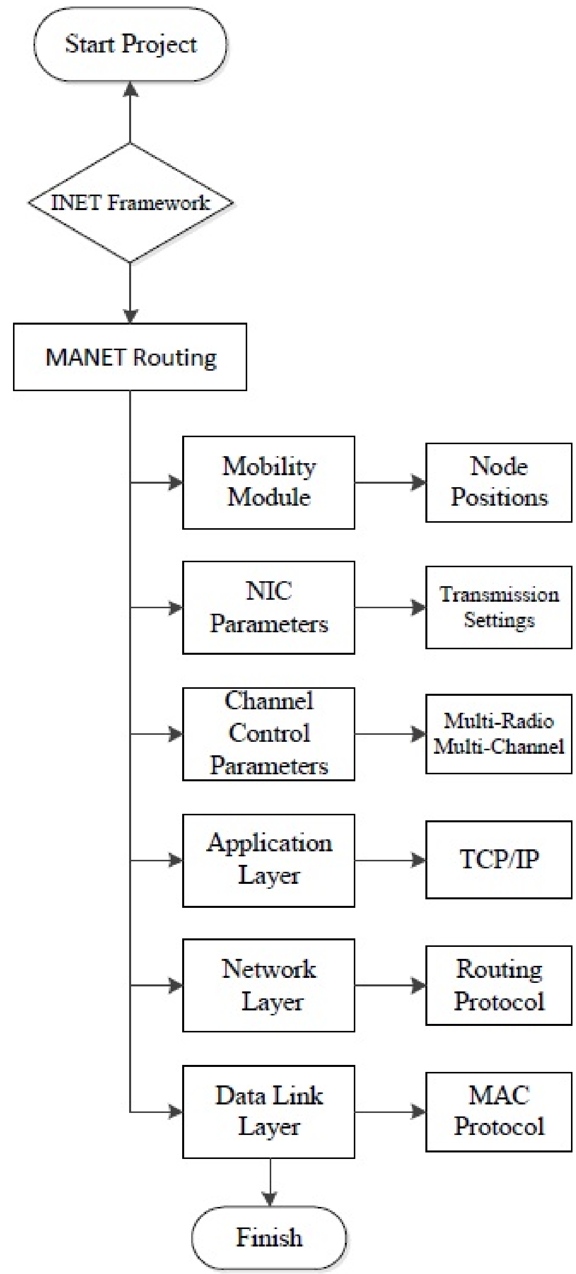

Fig. 2: Steps for multi-hop wireless network project design on OMNET++

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```
# mobility
**.drawCoverage= true
**.constraintAreaMinX = 0m
**.constraintAreaMinY = 0m
**.constraintAreaMinZ = 0m
**.constraintAreaMaxX = 1500m
**.constraintAreaMaxY = 1500m
**.constraintAreaMaxZ = 0m

**.host[*].mobilityType = "ConstSpeedMobility"
**.host[*].mobility.speed = uniform(10mps, 20mps)
**.host[*].mobility.updateInterval = 50ms
**.host[*].mobility.debug = default
```

Fig. 3: Mobility Parameters

into air frame. Air frame contains the physical parameters of radio channel. To build simulation model, OMNET++ provides a *opp_makemake tool* for *makefiles* generation. The *opp_makemake* translates the message files into C++ sources [7].

Following are the steps we need to build a model in OMNeT++.

- Create project
- Model designing (the NED file and C++ Codes)
- Project configuration ((the INI file)
- Build project
- Results analysis

Figure 2 shows the steps used in our proposed model of multi-hop wireless network. The first step is to select the new project and then INET frame which is used for multi-hop wireless network modelling. The INET framework consists of many sub frameworks including *adhoc*, *internet-cloud*, *Ethernet*, *IPv6*, *mobility*, *manetrouting* etc. We chose the *manetnetwork* for simulation as it has ability to select the various features including multi-radio and multi-channel. It consists of six different parameters: a) Mobility module, b) NIC parameters, c) Channel control parameters, d) Application layer, e) Network layer (routing protocol) and f) Data link layer (MAC protocol). In our proposed method, we used all these parameters and protocol to simulate the multi-hop network.

C. Mobility Models

The first step we need to do is to define simulation area. The scenario to model the office, campus or a city network is quite different. After selecting the simulation area, we should determine the position of nodes. This is done by mobility model. It could be *LinearNodeDistributionMobility*, *ConstantSpeedMobility* or others. The mobility model can be found in directory *src/mobility*.

The Figure 3 shows how the *constSpeedMobility* can be configured. The mobility constraint area (X, Y, Z), node speed and update interval are specified. As an example, the mobility speed is defined as uniform distribution between 10ms and 20ms. This is an example to show how we can set the constraint area and mobility parameters.

```
**.wlan*.radio.transmitterPower= 2mW
**.wlan*.radio.sensitivity= -90dBm
*.channelControl.carrierFrequency = 2.4GHz
*.channelControl.pMax = 2mW
*.channelControl.alpha = 2
*.channelControl.sat = -110dBm
*.channelControl.propagationModel = "FreeSpaceModel"
```

Fig. 4: Transmission Parameters

D. Propagation Models

The signal strength that a node receives according to distance to the source is determined by propagation model [12]. It highly affects the connectivity between nodes. It is defined in configuration file and is set to free space by default. In free space model, the signal loss related to distance is calculated as follow:

$$freespace = \left[\frac{c}{4 * pi * d * f}\right]^2 \tag{1}$$

Where d is the distance between receiver and transmitter. f represents utilized frequency and c is the speed of light. The signal strength of received packet P_r is calculated as P_r= P_t * *free space*. Where P_t is transmission power.

The coverage area of a node is determined by three parameters

- Propagation model
- Transmitter power
- Receiver sensitivity

These parameters can be configured easily in configuration file as shown in Figure 4.

The node coverage area radius is calculated as follow:

Propogation attenuation (dB) = Power emission (dBm) – Sensitivity (dBm)

ChannelControl is the module that provides the functionality to transmit the packets to neighboring nodes. This module determines the communication and interference distances of the nodes. OMNET++ considers that all channels are orthogonal which means that channels do not interfere with each other.

E. Link Layer and Mobile Routing Protocol

OMNET++ uses IEEE 802.11 standard to model wireless link layer protocol. The Figure 5 shows the ad-hoc node graphical representation. The network layer communicates with the MANET routing protocol. OMNET++ can support the modelling of 802.11a, 802.11b and 802.11g. However, the 802.11e can also be implemented in congestion with one of the previous protocol. The graphical representation of an IEEE 802.11g interface is shown in Figure 6. The radio layer, management layer and MAC layer have been separated in INET framework and InetManet framework. The management layer manages the queue and gets notification from MAC layer about its availability to accept packets. The size of the queue

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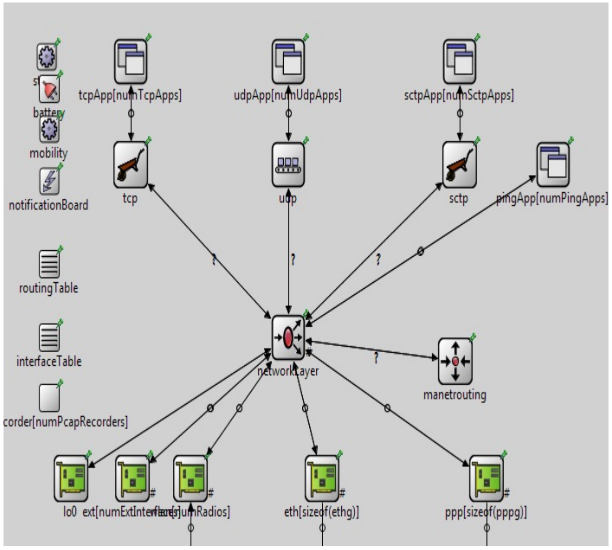

Fig. 5: Graphical representation of MANET routing node

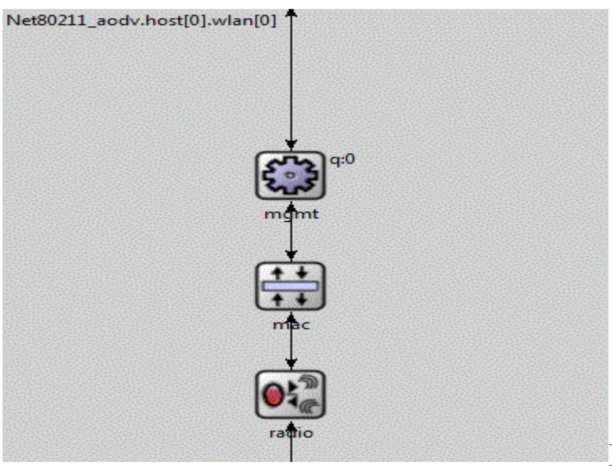

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Fig. 6: Graphical representation of an 802.11g interface

can be configured from configuration file. Radio layer has four following states.

- Receiving
- Transmitting
- Idle
- Sleeping

The radio layer sends notifications to the MAC layer when it changes its state. MANET protocols are usually used in multi-hop wireless network. They are directly connected to IP network layer module in InetManet. Setting up routing table is also important for multi-hopping. This is done by *autoconfigration* module. It assigns the addresses automatically and set a routing table basic configuration. The link layer class can also offer functionality like relocation of node (GPS base device) and timer triggering.

TABLE I: Simulation Parameters

Parameter	**Value**
Simulation time	60s
Carrier frequency	2.4 GHz
Network size	1500m x 1500m
Bitrate	54Mbps
Number of nodes	6
Wlan type	Ieee80211Nic
Max queue size	14
Number of channels	6
TCP application type	TCPSessionApp
Queue frame capacity	15
Routing protocol	OLSR
Mobility type	StationaryMobility
Max channel control power	2.0mW

F. Simulation Parameters

Our multi-hop wireless network in OMNET++ consists of 6 *adhocHost* nodes. The size of the playground is set to 1500m x 1500m. Control channel maximum power is set to 2.0mW and radio transmitter power is .2mW. It is necessary to set the radio transmitter power less than control channel power. In order to implement the multiple channels, we need to set the number of control channels. In our scenario we are using 6 channels. The number of radios in host [0] is set to 1. Whereas, host [1] to host [5] are using 2 radios each. In order for a node to communicate with each other, the intended nodes should be operating on the same channel number. Table I shows the parameters used in designing of multi-hop multiple channel wireless network.

IV. Simulation Results and Analysis

We analyzed the multi-hopping among 6 wireless nodes. The designed network is shown in Figure 7(a), 7(b) and 7(c). The circles around the nodes represent its transmission range. In this figure, we can see that only the neighboring nodes are within the transmission range of each other. Host [0] transmits the packet *(AirFrame)tcpseg(l=536)* to host [5] through relay nodes host [1], host [2], host [3] and host [4] as shown in Figure 7(b) and 7(c). The message received, sent and delivered have been illustrated in event recording shown in Figure 8.

Figure 9, 10, 11, 12 and 13 shows the overall transmission of packet and all the steps it takes to reach at destination (host [5]). In the Figure 9, we can see that *host [0].wlan [0].radio* (host [0], radio number 0) sends *tcpseg(l=536)* to *host[1].wlan [0]* (host [1], radio number 0). Upon receiving, the packet goes to the network layer. Network layer is connected to *ManetRouting* module that provides the next destination address. Then the network layer hand over this packet to node second radio which is connected to next node. The second radio is *host[1].wlan[1]*.

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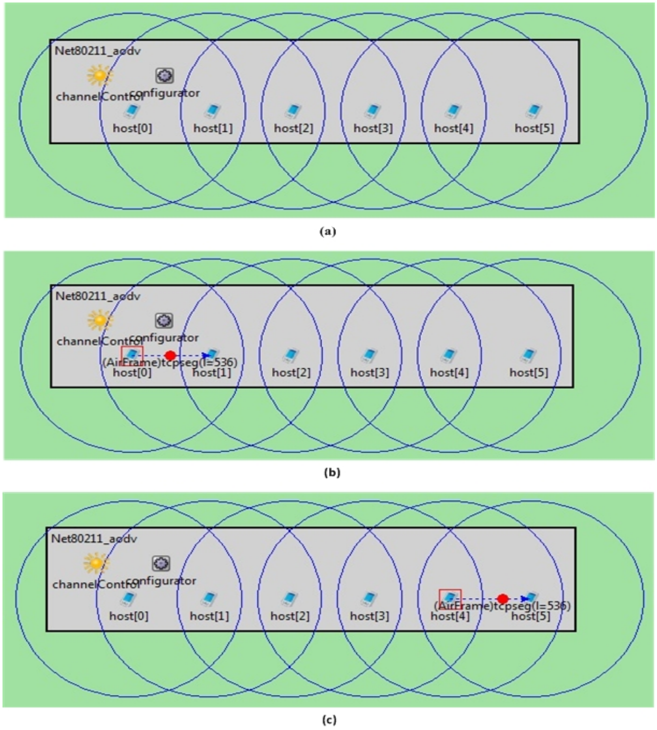

Fig. 7: Multi-hop wireless network in OMNET++

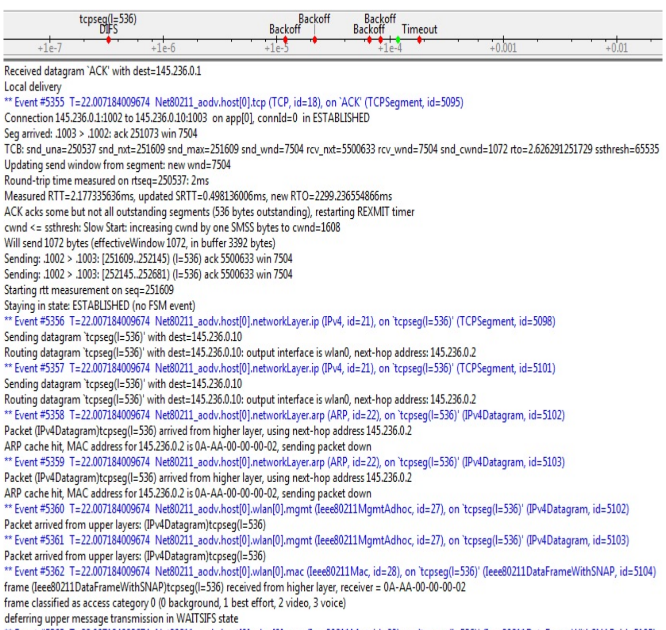

Fig. 8: Event regarding packet transmission in multi-hop wireless network

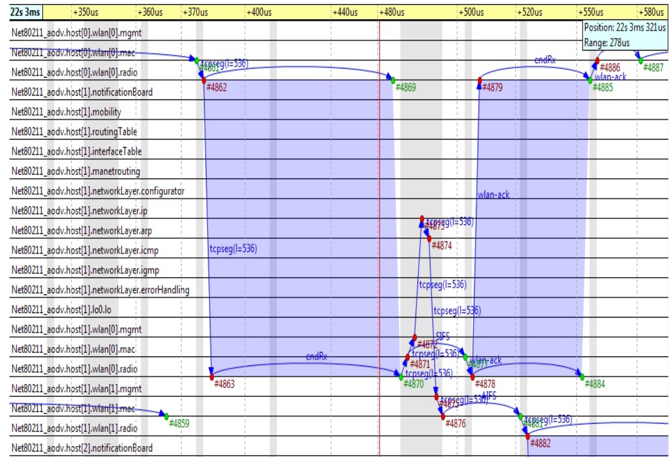

Fig. 9: TCP packet transmission from host[0] to host[1]

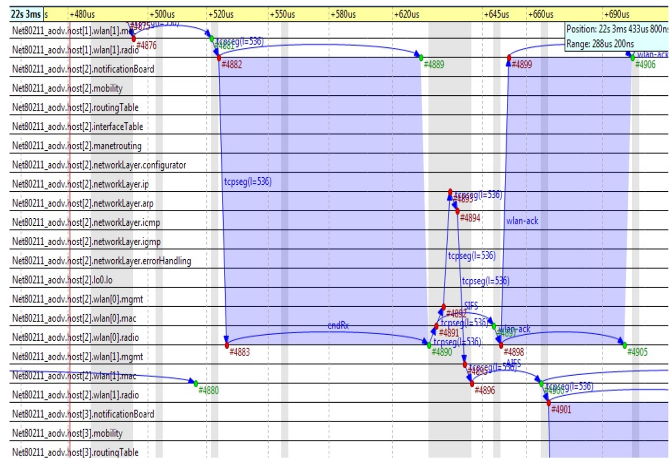

Fig. 10: TCP packet transmission from host [1] to host [2]

In Figure 10, we can see that *host [1].wlan [1].radio* forward this packet to *host [2].wlan [0].radio* at event 4882. The packet then goes to the network layer and gets the next destination address. The same procedure occurs at host [3] and host [4] as shown in Figure 11 and 12. When packet reaches at destination i.e., host [5] as shown in Figure 13, it sends back the *wlan ack* (wlan acknowledgement) packet to the node [0]. The *wlan ack* follows the same procedure from host [5] to host[0]. Host[0], after receiving *wlan ack* packet, sends next TCP segment in the same way. From the simulation, we also examined that the average packet delay and round trip time has direct relationship with number of hops. However, multi-hopping can increase the radio coverage without increasing the additional infrastructure cost.

V. Conclusion

In this paper, we provided the behavior and performance analysis of multi-hop wireless network. We used INET framework in OMNET++ simulation tool to study the multi-hopping procedure. Specifically, we described how available module can be used to simulate multi-hop wireless network. Further, we also explained the packet transmission of multi-hop network through concluded results. Generally, this simulation provides a better observance of working of INET framework, available module and their integration for multi-hop simulation.

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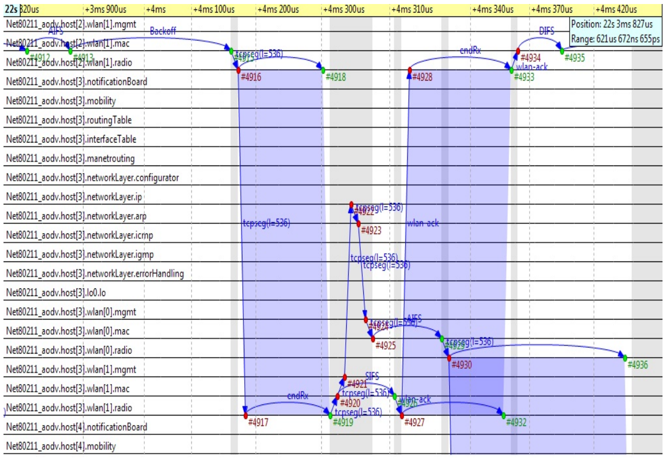

Fig. 11: TCP packet transmission from host [2] to host [3]

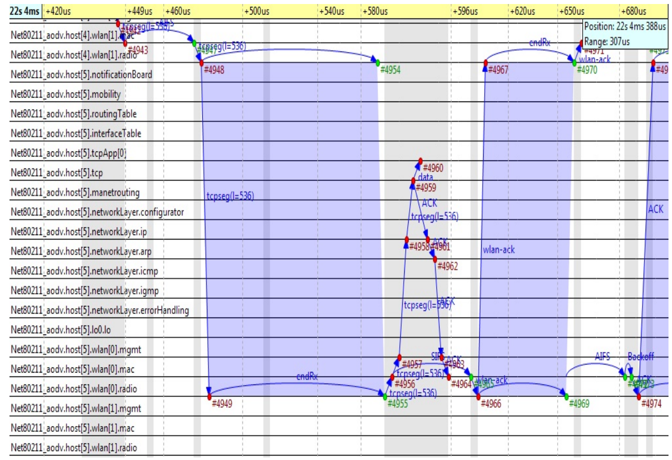

Fig. 13: TCP packet transmission from host [4] to host [5]

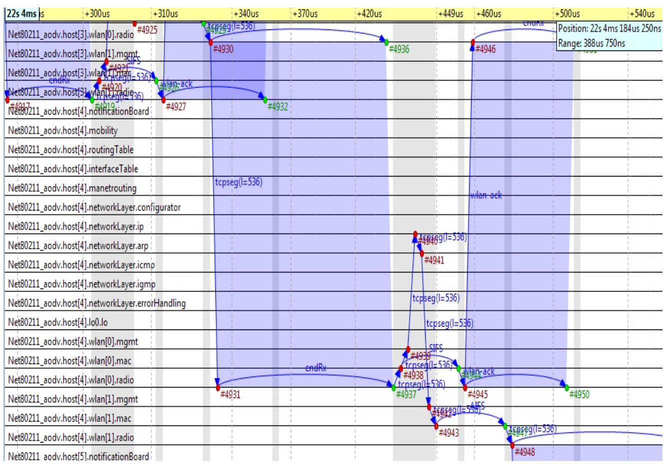

Fig. 12: TCP packet transmission from host [3] to host [4]

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