

Performance Analysis of mmWave on Military Scenario using Tactical Network Modeller

M. Munandar, I. Wayan Mustika, and Selo

Abstract—The utilization of millimeter wave (mmWave) for Military tactical communications remains a challenge. With its high data rate capacity characteristics, mmWave allows big data capacity communication to be forwarded. This is a challenge and an opportunity for military communication to harness the potential of this wave. This paper proposes a simulation in mmWave harness based on Military tactical communication. The net topology used was a tactical network modeler adapting a hierarchical Military organization. The simulation was built using network simulator 3 with C++ programming language. The parameters tested included end-to-end delay, jitter, and throughput. The best results showed that throughput 392.533 Kbps and 190.217 Kbps, end-to-end delay 4.500 ns and 24.500 ns, then jitter 1.212 ns and 13.125 ns, mmWave compare with LTE respectively on a military scenario using tactical network modeler. In addition, there will be challenges for further study.

Index Terms— mmWave, LTE, tactical network modeler, network simulator 3, programming language C++, military scenario.

I. INTRODUCTION

THE utilization of millimeter wave (mmWave) for communication systems is an important and viable opportunity [1]. As outlined in [2], the utilization of this wave can reach data rate up to 2 Gb/s at 1 Km for urban conditions. With such a large capacity, it allows large data to be passed, such as for streaming video, data communications, and others that can be utilized in a military operation. However, a fair communication system also supports success in military operations. On the other hand, military communication has a number of specific characteristics [3]. Specific research related to military communication becomes its own attraction, such as tactical troop communication [4]. One of the characteristics of military tactical communication is hierarchical [5]. This communication model allows the control and chain of command of the leader of the army to his troops. One method that supports this hierarchical system is the Tactical Network Modeller (TNM) [6] which is used to support communication between a commander with several

members subordinate members.

In previous work, mmWave has emerged and discussed. The majority of researchers focused on the electrical field as in [7][8][9]. Also, focused on the application but was not specific in military area as described in [10] [11]. More detailed research on tactical network communication in the military has presented in [12]. But this paper only discussed heterogenous tactical network performance analysis consisting of UHF, VHF, and SatCom by implementing OSLR protocol, not using mmWave. Another research related to the implementation of mmWave was conducted by [13]. In this paper, feasibility research was presented using mmWave in a simulation tool on several tactical network conditions with the main parameters measured related to energy consumption. This paper did not perform another parameter results. Also, the tactical scenario used has been explained in [14], it used architecture based on NATO standards, NATO IST-168 RTG (Research Task Group) implementing the Kubernetes open-source platform. It is pointed out that the results obtained, including the use of Kubernetes can be used for tactical networks. But did not use mmWave. So that, TNM in combination with mmWave has not shown deeply in performance analysis. Exactly to perform simulation as proof.

As proposed in this paper, we provided the performance analysis of the military scenario based on TNM, which was simulated by using network simulator 3 (NS-3) as an open-source application [15]. Furthermore, we also provide performance mmWave and LTE as a study comparison. Which is uniquely presented together in a military scenario. In the next section, this paper will discuss design tactical network modeler. Section 3 will discuss the simulation studied. Section 4 will discuss the results of the simulation. Finally, section 5 is to present the conclusions of the study.

II. DESIGN OF TACTICAL NETWORK MODELLER

A. Tactical Network Modeller Concept

Tactical Network Modeller (TNM) is a concept for the development of module-based simulations [6]. Thus, it enables the development of tactical networks to be built dynamically and hierarchically. In addition, TNM support models to be built using an Application Programming Interface (API) or a node-based User Interface (UI).

For the design development in this paper, TNM concept was reconstructed based on military scenario communication. The code used C++ and implemented Long Term Technology

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(LTE) and mmWave. Also, there were one Head Quarter (HQ) and 2 platoons, each of which consisted of 3 soldiers led by a commander.

TNM is presented as a modular concept to accommodate this purpose. It is not only to support hierarchical structure as a dominant in military, but also to support to be built with LTE and mmWave as modular to be simulated. These features have made the performance analysis more achievable.

B. Network Implementation Scheme

The scheme used on this network system was based on TNM. The utilization of each module was through several hierarchical troop objects. This scheme also supported the use of several other modules that are needed more easily.

Figure 1 shows a network implementation scheme created based on TNM. The network was built in a hierarchical manner consisting of HQ as the remote house, commanders (eNodeA and eNodeB), and mobile user equipment (EU) as mobile troops.

This network implementation will use mmWave as its communication medium. Also, the simulation was presented in LTE technology as a comparison performance.

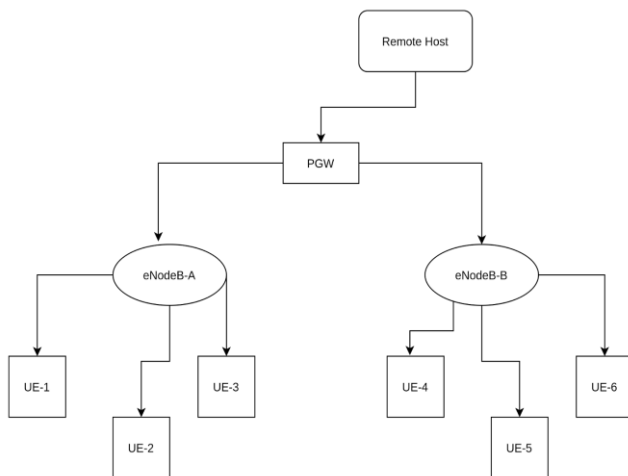


Fig. 1. Tactical Network Modeller implementation.

The implementation of the flow is described as follows:

1. Remote hosts send the packets to packet gateways (PGW) to eNodeB-A and eNodeB-B, respectively. This flow is in a simulated scenario as instruction or order from the headquarter.
2. PGW will forward the first data packet to eNodeA and eNodeB. These nodes are static. As a scenario a commander in the field gives direction to the subordinate.
3. eNodeA and eNodeB forward the data packets to the three EU that are in their auspices. Commander A to UE in its subordinate and commander B to UE in its subordinate.
4. The EU will respond to the packet of the data packet by sending back the response to the Remote Host via the same path in reverse from eNodeA or eNodeB and Then to PGW and Remote Host.

5. Step flow 2 and 4 are also implemented to EU devices on eNodeA and eNodeB shade.
6. The result simulation is captured using a flow monitor on NS-3 with its metric. The parameters measured are throughput, end-to-end delay, and jitter.

This model was used to describe a hierarchical structure in the military organization. We did a simulation in one headquarter divided into two platoons, each of which had one commander with three subordinate troops as shown in Fig 2.

This network scheme is adopted from the hierarchical structure in the military but is not specific to military-specific organizations which is used as an example of a scenario to be built in the simulator. Besides from the restriction of specific military tactical and strategical could be published. This scheme gives an alternative schema for networking in tactical network modeler scenario.

Structure tactical network could be combined not only by the human as troops, but also with vehicle, aircraft, tank, and others. But in this paper, the object was only for human mobility.

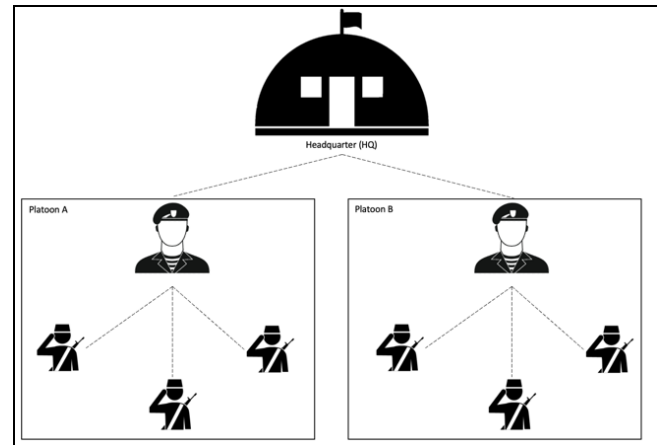


Fig. 2. Military Scenario with Hierarchical Structure.

III. CONFIGURATION OF SIMULATION

To perform this scheme, we used simulation and did not use the real testbed as it was restricted. It used Personal Computer (PC) with Ubuntu OS. The simulation was conducted using network simulator 3 (NS-3) with C++ programming language. This simulated source code can be accessed at [16].

Initial configuration performed with the settings for simulation as shown in Table 1. The number of remote hosts showed one as the headquarter (HQ) in its application. The number of eNodeB showed two commanders in field. The number of UE showed three subordinate members of each commander. This configuration also sets up mobility for subordinate members used random movement areas among 5 to 100 meters. The simulations were set one second per flow and then gave an internet data rate 100Gb/s. All these parameters used have been configured in the simulator.

TABLE I
PARAMETER SIMULATION

Parameter	Value
Number of Remote Host	1
Number of eNodeB	2
Number of UE each Node	3
UE Mobility	Random, Range 5-100 meters from eNodeB
eNodeB Mobility	Constant Position
Simulation Time	1 second/flow
Internet Data Rate	100 Gb/s

The performance analysis parameters studied included Throughput, end-to-end delay and jitter. The three parameters are explained below [17]:

- Throughput is a value that indicates the capacity or number of bits received when the network is active. The higher the throughput value indicates the better the quality. Throughput uses bit per second (bps) as a metric. Thus, several results are shown in Kilo as Kbps or in Mega as Mbps.
- End-to-end delay is a calculation result that shows the travel time from the sender node to the recipient node. The smaller the end-to-end delay value, the better the network quality. This parameter uses second as a metrics. Therefore, for the small data, several metrics use nanosecond as a metric as (ns). We used lowercase as a distinction with NS as network simulator means.
- Jitter is the magnitude of delay variation. The smaller the value of the jitter, the better the network quality. Similar metric with end-to-end delay, jitter also used ns as metric.

In this simulation, these three parameters were captured by a flow monitor. We provided the data capture presented originally and simplicity. As a proof a concept from the analysis we made as a contribution. TNM presents as a modular concept to accommodate this purpose. Using TNM every requirement was conducted as a modular. As we made in this paper LTE and mmWave we built in modular using C++ in network simulator 3.

Our simulation was run with several streams that tried flow several times. The results of the parameter data measured were then stored and then will be analyzed. In addition, this paper also discusses about the results of the scenario comparison in TNM. It used Long Term Evolution (LTE) and mmWave technology in simulation. Flow means an order or an instruction from HQ to soldier in the front of line through its commander. Thus, for every flow from HQ, the soldier must recall back or send confirmation back to HQ through the commander as an understanding of every order or instruction given. This flow executes hierarchical as found in a military scenario using hierarchical organization. So that, by using a flow monitor, we captured every data and analyzed its.

Flow monitor collected the metrics from parameters. In our simulation, we planned to highlight the seven flows.

Furthermore, data resulting could be generated in more than seven flows. This point number was only to highlight the important occurrences in the scenario.

IV. RESULT AND DISCUSSION

The simulation results showed that the use of mmWave in military scenarios using TNM excelled in the majority of aspect. In terms of simulations, the results of the calculations are presented as follows.

Our results obtained the data from every flow data sent by HQ to the UE/soldier through its commander. At this point, the commander in this scenario acted not only as a direction distributor but also as a packet data sender. As a summary, we presented a highlight data from our simulation study with NS-3, the data as shown in Table 2, captured by flow monitor. It showed seven flow capture data as a highlight.

TABLE II
SUMMARY RESULT OF SIMULATION

Flow	mmWave			LTE		
	Throughput (Kbps)	End to end delay (ns)	Jitter (ns)	Throughput (Kbps)	End to end delay (ns)	Jitter (ns)
1	107.811	4.50E+07	112	53.61	1.01E+07	0
2	107.811	4.50E+07	112	53.61	1.01E+07	0
3	167.185	4.50E+07	62	53.61	1.01E+07	0
4	167.185	4.50E+07	62	82.8711	1.01E+07	0
5	392.533	4500	1212	190.217	24500	13125
6	392.533	4500	1212	190.217	24500	13125
7	392.533	4500	1212	190.217	24500	13125

Furthermore, data were shown in a visual graphic form and compared. We highlighted the data capture from flow monitor. To make it simple by readers, the discussion tells will provide more visualization and brief explanation. As shown in Fig 3, the simulation results proved that mmWave had a greater bandwidth capacity. The experimental test was conducted using network simulator 3 using the programming language C++ with seven times. The flow obtained that the value of throughput was getting bigger. Although at the beginning, the result showed that throughput values were not too large. Then, with several times the flow obtained higher results. As compared to LTE, mmWave implementation in the simulation was much more outperforming.

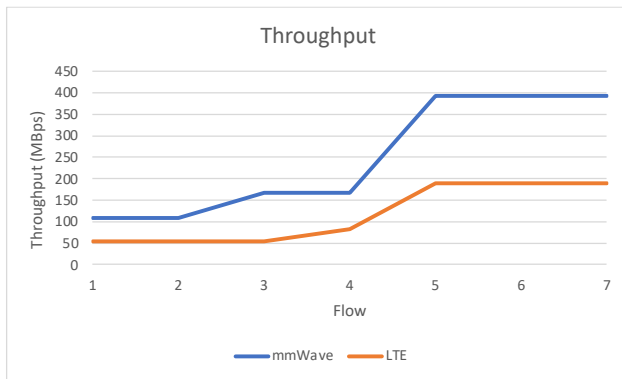


Fig. 3. Throughput Result.

On the measurement of end-to-end delay parameters, there was a significant decrease in the fifth-flow experiment until completion. The best point we got was the value of 4500 ns at last. As mentioned earlier, the smaller the value of this parameter, the better it will be as shown in Figure 4.

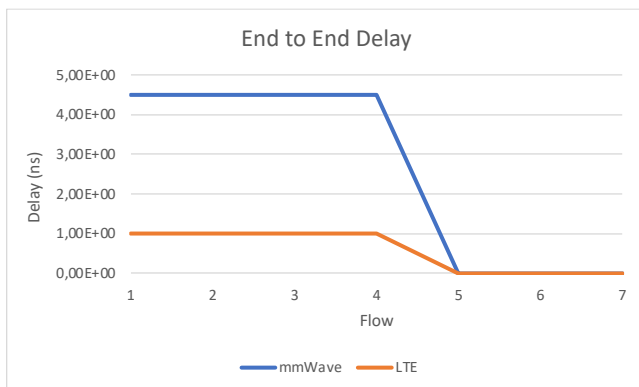


Fig. 4. End to end Delay Result.

The last parameter tested was jitter. In this parameter, the simulation results also showed a better value, as shown in the following Fig 5.

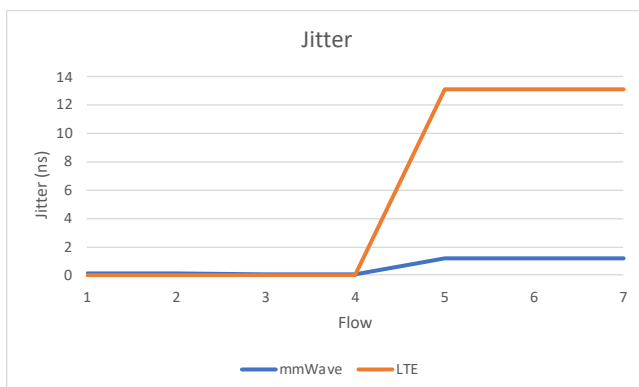


Fig. 5. Jitter Result.

These results showed the culmination point in the fourth flow and fifth flow, respectively. This showed that every condition has given different results. Especially in random mobility. But, in this point (fourth and fifth flow) throughput showed the highest performance indicating the medium achieved a stable condition. This showed that configuration

met with step forward to optimization. This argument also occurred in delay and jitter parameters. This scenario performed well after the fourth flow. Exactly in fifth flow, the performances were outperformed because the stable condition.

V. CONCLUSION

The use of mmWave technology in military scenarios is a very interesting area. Using mmWave could give more potential benefits that can be achieved. Through simulations in this paper, mmWave utilization for military scenarios using TNM was presented. Combination with TNM was used as modular to be applied to obtain appropriate results in the conditions of military hierarchical organizations. This scheme was performed by simulation built in NS-3, using the C++ programming language (several modules from NS-3 were also conducted). The simulation results obtained several test parameters showing that mmWave had a throughput, end-to-end delay and jitter was quite good. Especially when compared to the use of LTE technology. MmWave could provide some good results in the majority. The best results showed that throughput 392.533 Kbps and 190.217 Kbps, end-to-end delay 4.500 ns and 24.500 ns, then jitter 1.212 ns and 13.125 ns, mmWave compared with LTE respectively on a military scenario using TNM. Also, as our contribution in this paper, we provide the source code in a network simulator using C++ programming language which can be used as an opensource.

As future work, mmWave research will be simulated in multi-hop tactical conditions and combined with the Mobile Adhoc Network (MANET) routing protocol. Because of MANET have specific criteria to be deploy in a military scenario. It is mobile, wireless, and no need infrastructure. These criteria could match the operational requirement in the military scenario as in emerged.

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