ECE 659 Assignment 1

Group 27

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Question: 1

IoT protocol	*Layer*	*Standard*	*Data Range*	*Range*	*Frequency Band*	*Topology*	*Power Req.*
IEEE 802.15.4	Physical	IEEE 802.15.4	250 kbps @ 2.4GHz 40 kbps @ 915MHz 20kbps @ 968MHz	10m to 100m	2.4GHz, 915MHz, 868MHz	Star, Peer to Peer Topology	1-100mW
IEEE 802.11 ah	Physical	IEEE 802.11ah	0.15-4Mbps @ 1MHz 0.65-7.8Mbps @ 2MHz	100 - 1000m	863-869MHz (Europe) 902-928MHz (US) 916.5-927.5 MHz (Japan)	Single Hop Topology	<10mW-<1W depending on country's regulation
Wireless HART	Transport	IEEE 802.15.4 and IEC 62591	250kbps	About 100m	2.4 GHz	Star and Mesh topology	Min 10mW
Bluetooth LE	Physical	IEEE 802.15.1	2Mbps, 1Mbps, 500kbps, 125kbps Based on LE configurations	<100m	2.4 GHz based on ISM band	Point-to-point Broadcast and Mesh topology	0.01 to 100mW
LTE-A	Transport	3GPP standard	1.5 Gbps uplink 3 Gbps downlink	5 km to 10 km	1.4, 3, 5, 10, 15 or 20 MHz	Point-to-Multipoint, peer-to-peer Topology	low
Wi-Fi	Physical and Data Link Layer	IEEE 802.11 (currently 802.11 ax)	2.4Gbps	150 feet indoor and 300 feet	2.4 GHz, 5 GHz	Star, Point-to-point Topology	low

				outdoor			

References are taken from the protocol papers posted on learn and the links mentioned as follows:

- https://www.electronics-notes.com/articles/connectivity/ieee-802-15-4-wireless/basics-tutorial-primer.php#:~:text=The%20concept%20of%20IEEE%20802.15,data%20rates%20of%20250%20kbps.
- https://www.sciencedirect.com/science/article/pii/S2405959516300650
- https://www.rfwireless-world.com/Terminology/Zigbee-vs-WirelessHART.html
- https://en.wikipedia.org/wiki/Bluetooth_Low_Energy
- https://www.bluetooth.com/learn-about-bluetooth/tech-overview/
- https://www.3gpp.org/technologies/keywords-acronyms/97-lte-advanced
- https://www.intel.ca/content/www/ca/en/support/articles/000005725/wireless/legacy-intel-wireless-products.html
- https://www.tomshardware.com/reviews/local-area-network-gigabit-ethernet,3035-7.html

Question: 2

No, the MAC protocols of the IEEE802.11 standard cannot be used in IoT networks that run on very constrained devices although it is able to meet the intensive performance requirements and demands of the IoT network due to the following reasons:

• There is no necessity to utilize a high-overhead high delay MAC Protocol when only a few periodic packets need to be sent in the IoT network

• It does not support energy consumption and scalability

• It also causes high network throughput and low latency

Question 3 (7 points) –

In a data link layer the flow control is performed using the Stop and Wait protocol, if you are to define the minimum frame size to ensure 50% channel utilization show how to define this number. For the data rate use 8Kbps and the propagation delay is 100 msec.

Solution –

Given,
Channel utilization (u) = 50% = 50/100 = 0.5
Data rate (r) = 8kbps
Propagation delay (tp) = 100msec
Let, Transmission time = tt
Frame size = f

We know that,
Channel utilization (u) = Active time of sender / Total time of 1 cycle $= (t_t) / (t_t + 2* t_p)$
Substituting the given values, the above equation can be written as –
$0.5 = (t_t) / (t_t + 2 * 100msec)$
Solving the above equation –
$0.5 * t_t + 0.5 * 2* 100 \text{ msec} = t_t$
$0.5\ t_t = 0.5 * 2 * 100 \text{ msec}$
Transmission time = t_t = 200 msec

We know that,
Transmission time (t_t) = frame size / bit rate = f/r
Substituting the values, the above equation can be written as –
200 msec = f / 8 kbps
$f = 200 * 10^{-3} * 8 * 10^3$
Frame size = f = 1600 bits
Hence, the minimum frame size to ensure 50% channel utilization is **1600 bits**.

Question 4:

Given data:

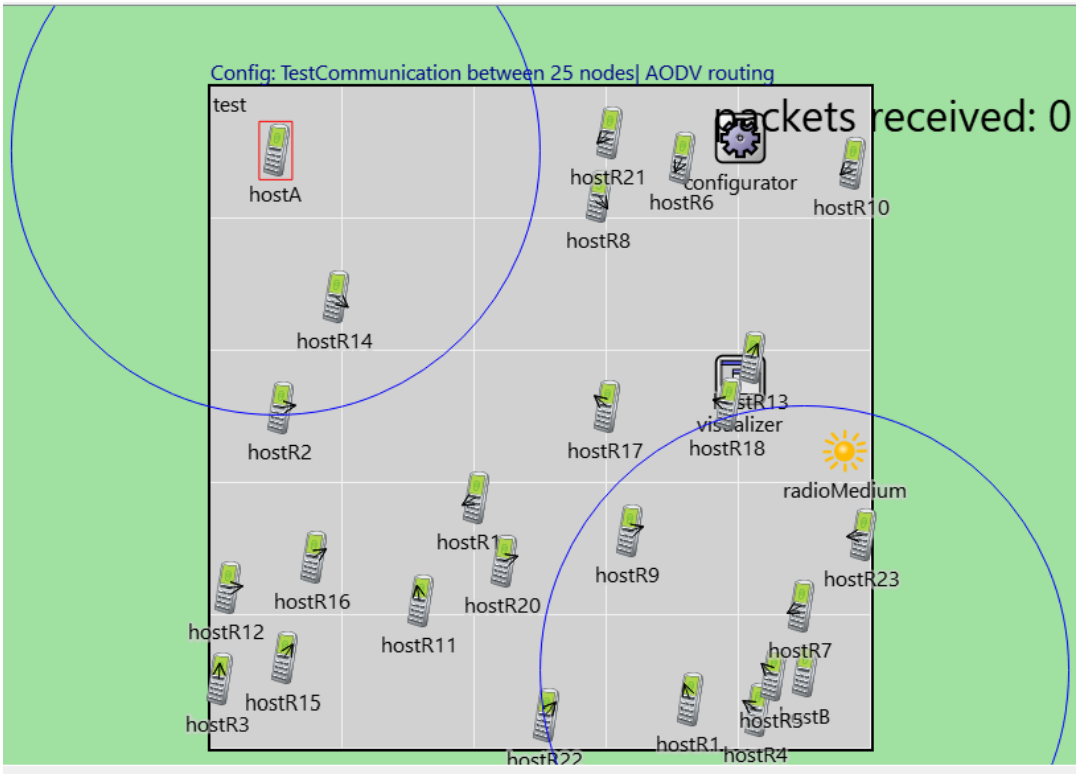
No of hosts = 25
Area of field = 500*500m
Simulation Time = 900s
Routing algorithm = AODV
MAC layer = IEEE 802.11
Data Rate = 11Mbps
Sending Rate = 3 packets/sec
Packet Size = 512 bytes
Mobility Speed = 1-20m/s

Our settings:

- We have kept the communication range of host A and host B to 200 m.
- All the hosts from R1 to R23 have a communication range of 250 m.
- Host A is the source node and Host B is the destination node.
- Host A and Host B are stationary as shown in the figure and the rest of the nodes are moving wrt to the type of mobility.
- Packet queuing capacity is kept to 10.
- Port of A and B is 5000.
- 1 packet is sent in 0.33 seconds.
- Packets send by host A are (900s/0.33s) 2727 packets.
- Mobility used: (i) Random Waypoint and (ii) Linear Mobility

(i) Random Waypoint Mobility:

The field view of the nodes in random is as shown in figure below:



Ned File: The below image shows the configurations used for the location of hosts, configurator, radio medium used, etc.

```
import inet.networklayer.configurator.ipv4.Ipv4NetworkConfigurator;
import inet.node.contract.INetworkNode;
import inet.physicallayer.wireless.common.contract.packetlevel.IRadioMedium;
import inet.visualizer.contract.IIntegratedVisualizer;

network test
{
    parameters:
        @display("bgb=500,500;bgg=100,1,grey95");
        @figure[title](type=label; pos=0,-1; anchor=sw; color=darkblue);

        @figure[rcvdPkText](type=indicatorText; pos=380,20; anchor=w; font=,18; textFormat="packets received: %g"; initialValue=0);
        @statistic[packetReceived](source=hostB.app[0].packetReceived; record=figure(count); targetFigure=rcvdPkText);

    submodules:
        visualizer: <default(firstAvailableOrEmpty("IntegratedCanvasVisualizer"))> like IIntegratedVisualizer if typename != "" {
            @display("p=401.18402,221.76001");
        }
        configurator: Ipv4NetworkConfigurator {
            @display("p=401.18402,39.312");
        }
        radioMedium: <default("UnitDiskRadioMedium")> like IRadioMedium {
            @display("p=480,275");
        }
        hostA: <default("WirelessHost")> like INetworkNode {
            @display("p=49.392002,48.384003");
        }
        hostB: <default("WirelessHost")> like INetworkNode {
            @display("p=449.56802,441.504");
        }

        hostR1: <default("WirelessHost")> like INetworkNode {
            @display("p=149.184,349.776");
        }
        hostR2: <default("WirelessHost")> like INetworkNode {
            @display("p=247.968,349.776");
        }
        hostR3: <default("WirelessHost")> like INetworkNode {
            @display("p=349.776,449.56802");
        }
        hostR4: <default("WirelessHost")> like INetworkNode {
            @display("p=59.472,449.56802");
        }
        hostR5: <default("WirelessHost")> like INetworkNode {
            @display("p=149.184,449.56802");
        }
        hostR6: <default("WirelessHost")> like INetworkNode {
            @display("p=449.56802,247.968");
        }
        hostR7: <default("WirelessHost")> like INetworkNode {
            @display("p=149.184,247.968");
        }
        hostR8: <default("WirelessHost")> like INetworkNode {
            @display("p=247.968,449.56802");
        }
        hostR9: <default("WirelessHost")> like INetworkNode {
            @display("p=49.392002,247.968");
        }
        hostR10: <default("WirelessHost")> like INetworkNode {
            @display("p=446.544,59.472");
        }
        hostR11: <default("WirelessHost")> like INetworkNode {
            @display("p=247.968,247.968");
        }
        hostR12: <default("WirelessHost")> like INetworkNode {
            @display("p=247.968,159.264");
        }
        hostR13: <default("WirelessHost")> like INetworkNode {
            @display("p=149.184,147.168");
        }
        hostR14: <default("WirelessHost")> like INetworkNode {
            @display("p=446.544,147.168");
        }
        hostR15: <default("WirelessHost")> like INetworkNode {
```

```
            @display("p=349.776,247.968");
        }
        hostR16: <default("WirelessHost")> like INetworkNode {
            @display("p=349.776,159.264");
        }
        hostR17: <default("WirelessHost")> like INetworkNode {
            @display("p=349.776,349.776");
        }
        hostR18: <default("WirelessHost")> like INetworkNode {
            @display("p=49.392002,349.776");
        }
        hostR19: <default("WirelessHost")> like INetworkNode {
            @display("p=446.544,349.776");
        }
        hostR20: <default("WirelessHost")> like INetworkNode {
            @display("p=247.968,48.384003");
        }
        hostR21: <default("WirelessHost")> like INetworkNode {
            @display("p=343.728,59.472");
        }
        hostR22: <default("WirelessHost")> like INetworkNode {
            @display("p=135.072,39.312");
        }
        hostR23: <default("WirelessHost")> like INetworkNode {
            @display("p=49.392002,147.168");
        }
}

```

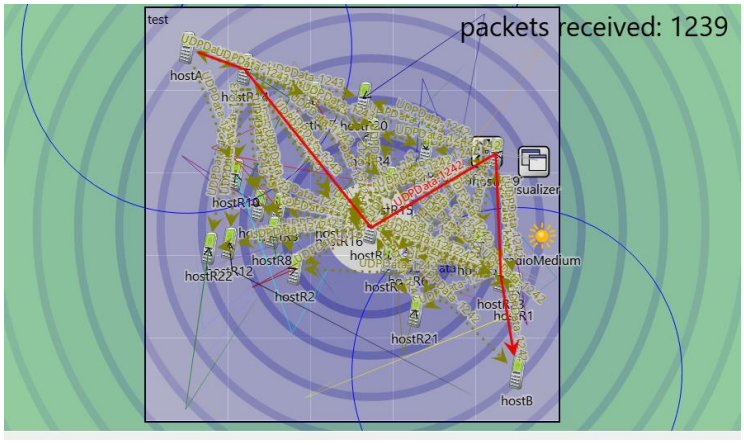
Ini File:

The configurations and parameters used for our simulation for Random waypoint mobility is shown below. The configurations for Linear Mobility will be shown in that section, rest of the parameters are kept same for both the mobilities.

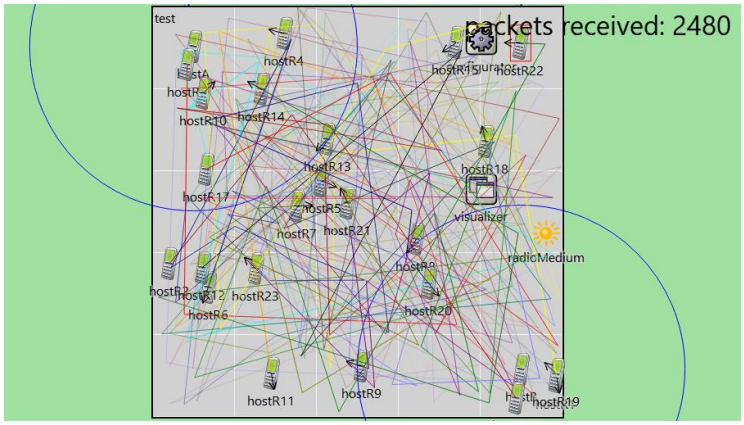
```
[Config ]
network = test
description = TestCommunication between 25 nodes| AODV routing
sim-time-limit = 900s

#500*500m field
**.constraintAreaMinX = 0m
**.constraintAreaMinY = 0m
**.constraintAreaMaxX = 500m
**.constraintAreaMaxY = 500m
**.constraintAreaMinZ = 0m
**.constraintAreaMaxZ = 0m

*.host*.ipv4.arp.typename = "GlobalArp"

*.hostA.numApps = 1
*.hostA.app[0].typename = "UdpBasicApp"
*.hostA.app[0].destAddresses = "hostB"
*.hostA.app[0].destPort = 5000
*.hostA.app[0].messageLength = 1000B
*.hostA.app[0].sendInterval = 0.33s #1 packet is sent after 0.33s
*.hostA.app[0].packetName = "UDPData"

*.hostB.numApps = 1
*.hostB.app[0].typename = "UdpSink"
*.hostB.app[0].localPort = 5000


*.host*.wlan[0].mac.fullDuplex = false
*.host*.wlan[0].radio.receiver.ignoreInterference = true
*.host*.wlan[0].mac.headerLength = 23B
*.host*.**.bitrate = 11Mbps


#////////////////////////////
*.hostA.wlan[0].radio.displayCommunicationRange = true
*.visualizer.sceneVisualizer.descriptionFigure = "title"
*.visualizer.mediumVisualizer.displaySignals = true
*.visualizer.physicalLinkVisualizer.packetFilter = "UDPData*"

#////////////////////////////
*.hostR*.wlan[0].radio.transmitter.communicationRange = 250m
#*.hostR1.wlan[0].radio.displayCommunicationRange = true
*.host*.forwarding = true
*.configurator.config = xml("<config><interface hosts='**' address='10.0.0.x' netmask='255.255.255.0'/><autoroute metric='errorRate'/></config>")
*.configurator.optimizeRoutes = false
*.host*.ipv4.routingTable.netmaskRoutes = ""

#////////////////////////////////////////////
*.visualizer.physicalLinkVisualizer.displayLinks = true
*.visualizer.dataLinkVisualizer.displayLinks = true
*.visualizer.networkRouteVisualizer.displayRoutes = true
*.visualizer.*LinkVisualizer.lineShift = 0
*.visualizer.networkRouteVisualizer.lineShift = 0
*.visualizer.networkRouteVisualizer.packetFilter = "UDPData*"
#////////////////////////////////////////////////
*.host*.wlan[0].mac.useAck = true

*.hostA.wlan[0].radio.transmitter.communicationRange = 200m
*.hostB.wlan[0].radio.transmitter.communicationRange = 200m
*.hostB.wlan[0].radio.displayCommunicationRange = true

*.configurator.addStaticRoutes = false
*.host*.typename = "AodvRouter"
*.hostB.wlan[0].radio.displayCommunicationRange = true
*.visualizer.dataLinkVisualizer.packetFilter = "AODV*"


##Random WayPoint Mobility
**.hostR*.mobility.typename = "RandomWaypointMobility"
**.hostR*.mobility.speed = ${speed = 1..20 step 1}mps
**.hostR*.mobility.initFromDisplayString = false
**.hostR*.mobility.waitTime = uniform(3s,8s)
*.host*.wlan[0].queue.packetCapacity = 10

#Mac as IEEE802.11
*.host*.wlan[*].mgmt.typename = "Ieee80211MgmtAdhoc"
*.host*.wlan[*].agent.typename = ""
*.host*.wlan[*].radio.typename = "Ieee80211UnitDiskRadio"
*.host*.wlan[*].radio.transmitter.communicationRange = 200m #Communication range for each host configured as 200 meters
*.host*.wlan[*].bitrate = 11Mbps #Bit rate = 11 Mbps
#*.hostR5.wlan[0].radio.displayCommunicationRange = true
*.visualizer.mobilityVisualizer.displayVelocities = true
*.visualizer.mobilityVisualizer.displayMovementTrails = true
```

Simulation Image: The below image shows an instance during a particular time period at a particular speed.

During Simulation:

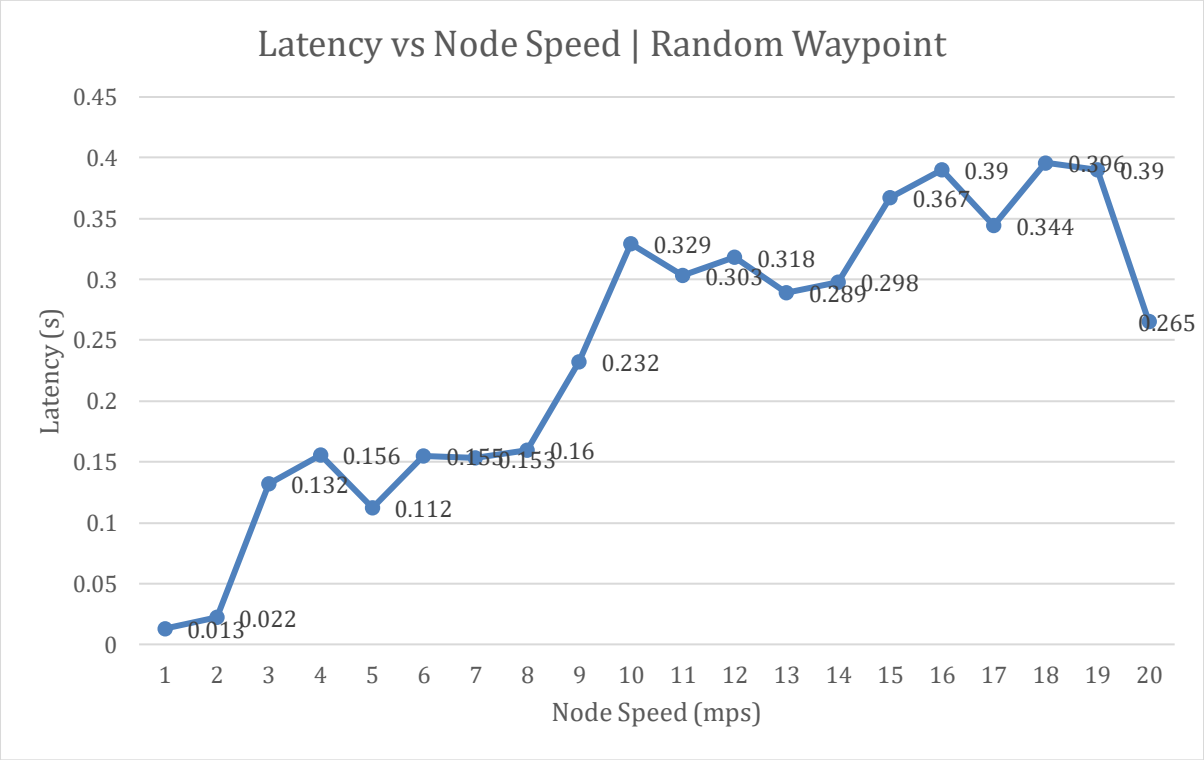


After Simulation:

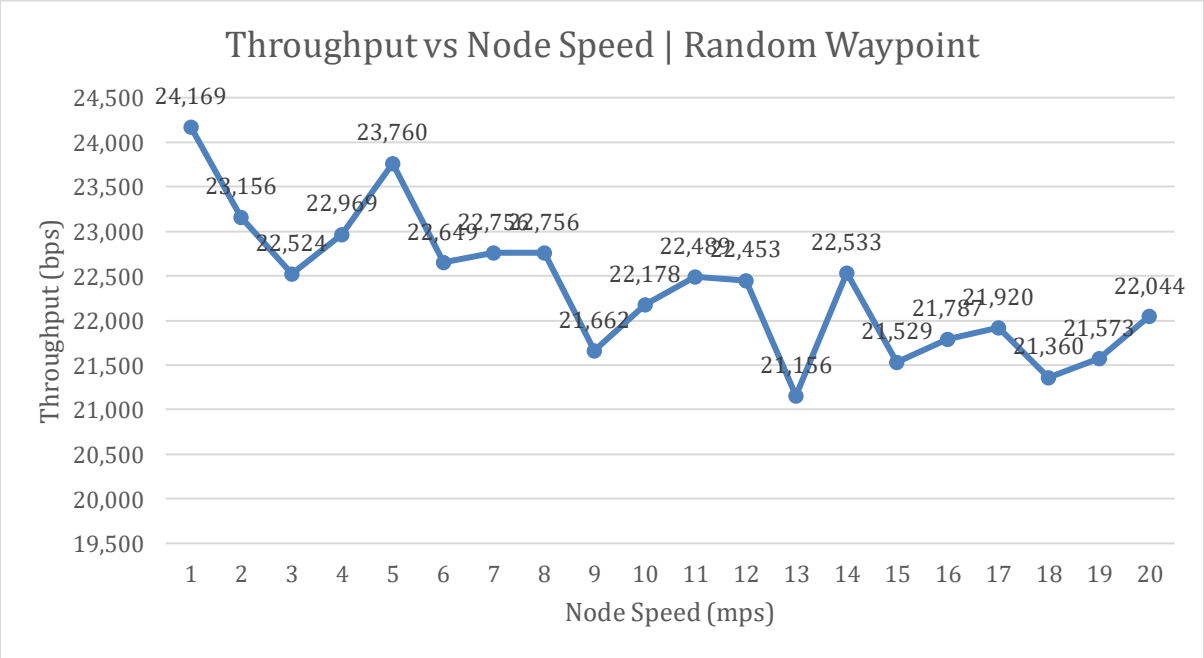


Plots:

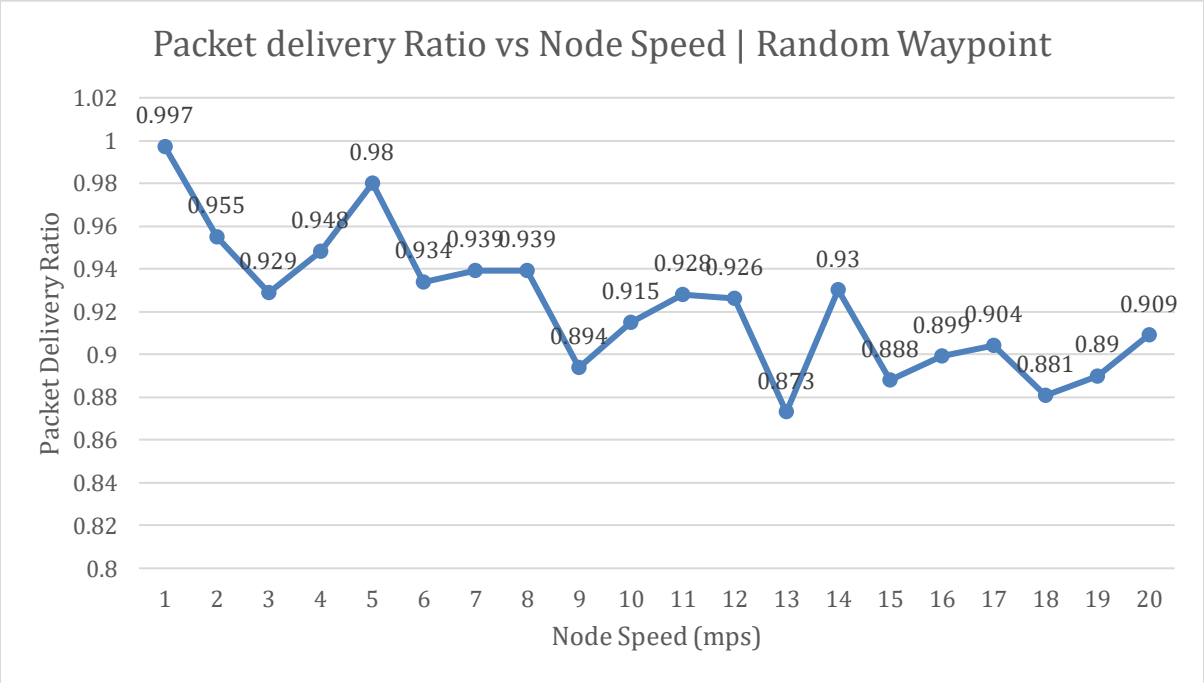
The plot for latency vs node speed for random waypoint mobility is as shown:



The plot for Throughput vs node speed for random waypoint mobility is as shown:



The plot for Packet Delivery Ratio vs node speed for random waypoint mobility is as shown:



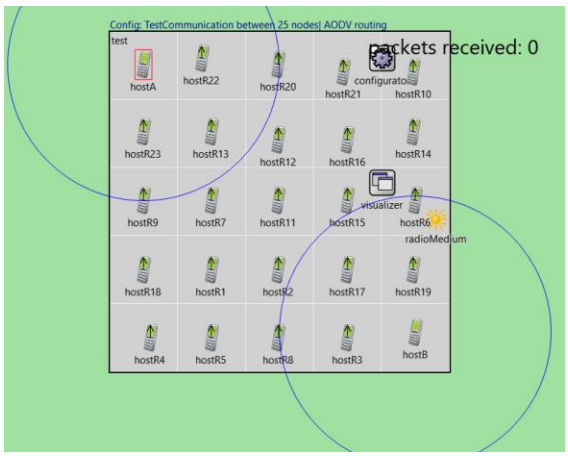
Analysis for Random waypoint mobility:

From the plot of latency vs node speed, it is seen that for random waypoint mobility, the latency increases with increase in speed of the node. This might be due to the fact that as the speed is increasing rapidly, our nodes are finding more time to recalculate the routing path and thus the increase in latency. From the plot of throughput vs node speed, it is seen that there is a downward trend in the graph with respect to the node speed. As the speed is increasing the rate of a packet sent successfully also decreases and hence packet loss.

Finally, for the graph of packet delivery ratio, the packet sent during our period of 900s is 2727, it is seen that the packet delivery ratio decreases with increase in the node speed which indirectly also help in understanding the downward trend for throughput vs node speed.

(ii) Linear Mobility:

The field view of the nodes in linear is as shown in figure below:



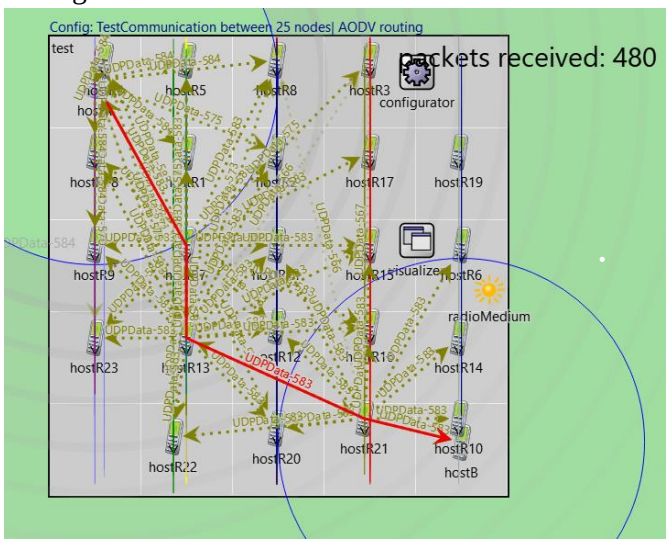
Ini File:

The configurations and parameters used for our simulation for Linear mobility is shown below. Rest all configurations are kept same as Random Waypoint mobility.

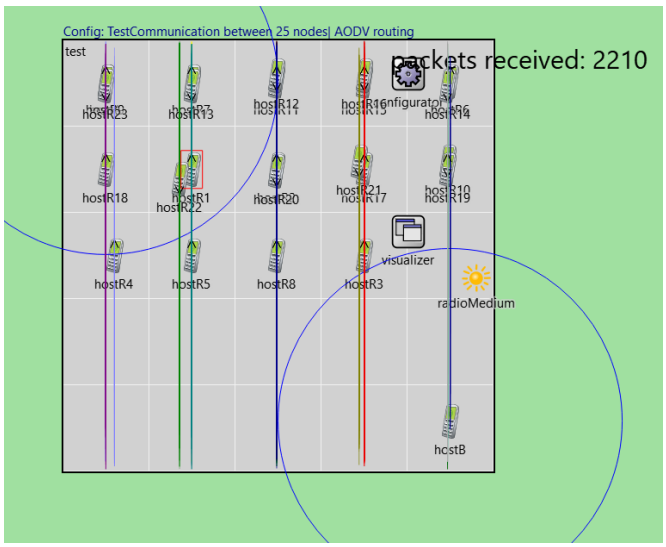
```
67
68 ##Linear Mobility
69 *.hostR*.mobility.typename = "LinearMobility"
70 *.hostR*.mobility.speed = ${speed = 1..20 step 1}mps
71 *.hostR*.mobility.initialMovementHeading = 270deg
72 *.host*.wlan[0].queue.packetCapacity = 10
73
```

Simulation Image: The below image shows an instance during a particular time period at a particular speed.

During Simulation:

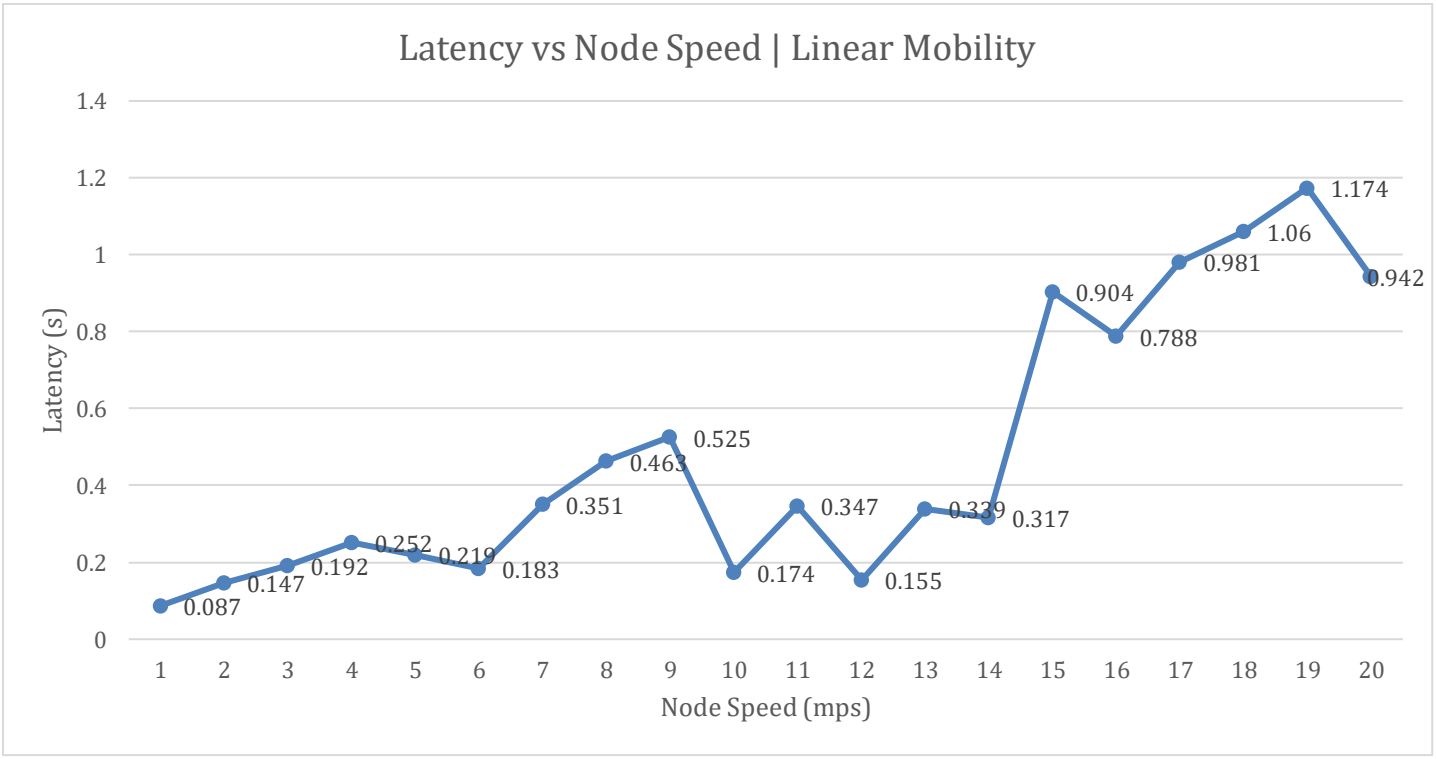


After Simulation:

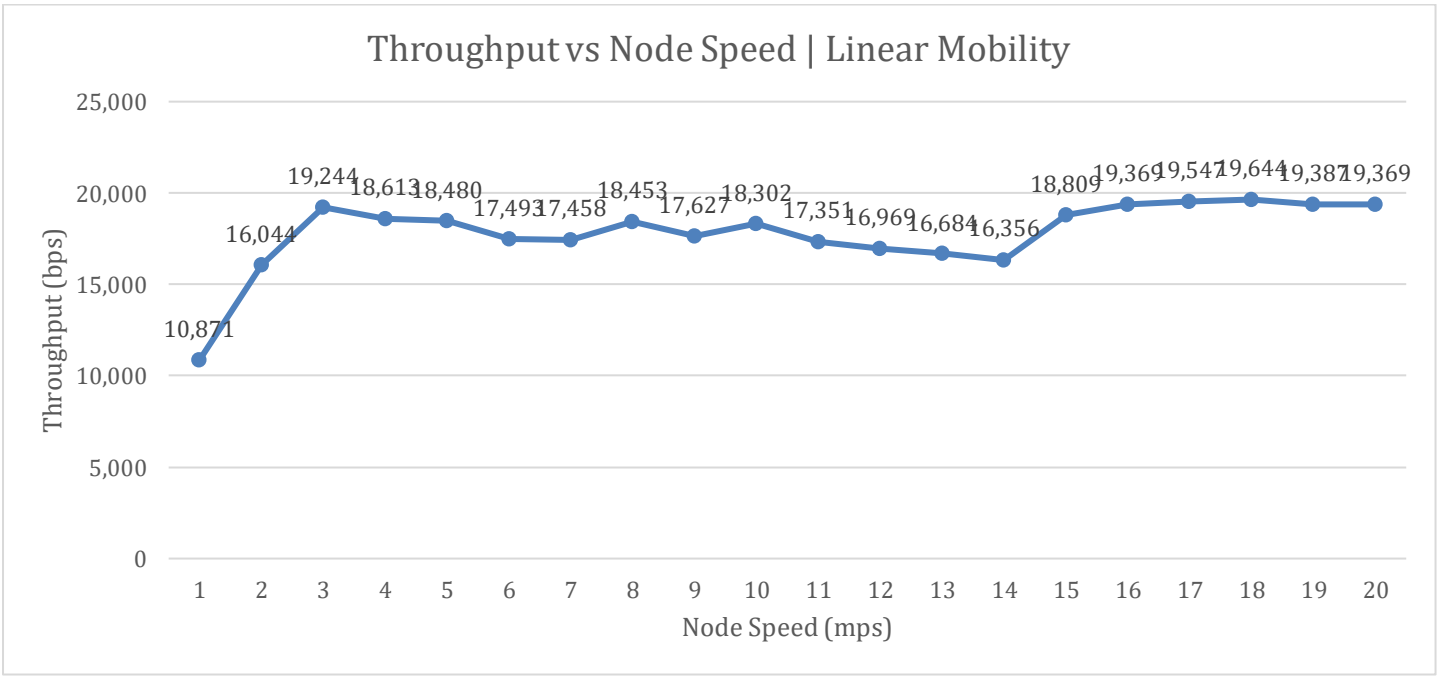


Plots:

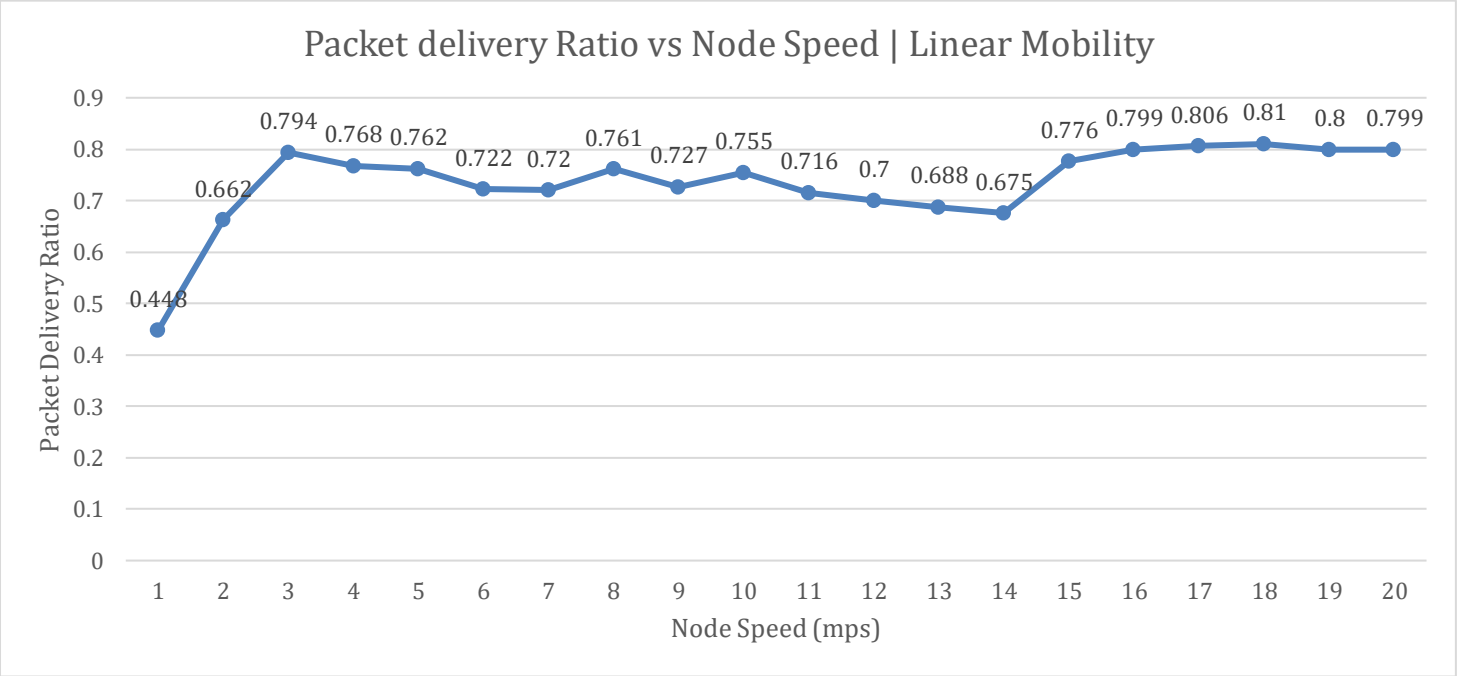
The plot for latency vs node speed for Linear mobility is as shown:



The plot for Throughput vs node speed for Linear mobility is as shown:



The plot for Packet Delivery Ratio vs node speed for Linear mobility is as shown:



Analysis for Linear mobility:

For linear mobility as compared to random waypoint mobility, we are seeing an increase in the latency as the speed of the node increases. The latency values are significantly higher in linear mobility as compared to the random waypoint.

From the next plots of throughput and packet delivery ratio vs node speed, there seems to be a relation between them. As the node speed increases, both throughput and packet delivery ratio increase sharply till the speed of 3. The values are lower at the start, this is due to the arrangements of our nodes, there might be a time where all the nodes have moved to one side of the field and that's when the packet delivered between source node A and destination node B is lost for a longer period of time as the speed is 1-3m/s. Even though the throughput and packet delivery ratio maintain a steady rise, but the values are way less as compared to random waypoint mobility. This shows that Random waypoint mobility is more suitable to our network as compared to Linear mobility.