1.
What wireless network modules are available in ns-3?

- 6LoWPAN module (6LoWPAN compression of IPv6 packets)
- AODV Routing module
- Applications module
    - BulkSendApplication (This traffic generator simply sends data as fast as possible)
    - OnOffAplication (This traffic generator follows and On/Off pattern)
    - PacketSink
    - UdpClientServer
    - UdpEcho
- CSMA Module
- Click Routing Module
- Core Module
- DSDV Routing Module
- DSR Routing Module
- File Descriptor Network Device Module
- Internet Module (IPv4, IPv6, TCP, UDP)
- Internet Applications Module (DHCPv4 Client and Server, Ping6, Radvd, V4Ping)
- LTE Module
- Mesh Module
- Network Module
- Network Animation Module
- OLSR Routing Module
- OpenFlow Module
- Point-to-Point Module
- UAN Module
- WiMax Module
- Wifi Module

Consider Data Link Layer (i.e. MAC protocol modules) and Network Layer (i.e. routing protocol modules)

- Data Link Layer (i.e. MAC protocol modules)
    - Mesh Device Module
        - FLAME (Forwarding Layer for Meshing protocol)

- Network Layer (i.e. routing protocol modules)
    - AODV Routing
    - Click Routing
    - DSDV Routing
    - DSR Routing

- IPv4 / IPv6 Routing Protocol
- Nix-Vector Routing
- OLSR Routing

In What directories are they located?

- ns-3-allinone/ns-3-dev/src/
- ns-3-allinone/ns-3-dev/build/ns3 (Header Files)
- ns-3-allinone/ns-3-dev/build/src

2. OLSR and DSR are two mobile network routing protocols. Briefly describe their similarities and differences.

- OLSR (Optimized Link State Routing Protocol) is the IP Routing Protocol which is optimized mobile ad-hoc networks. Before data is requested, OLSR creates the routing table by calculating the path in advance. This is a proactive link-state routing protocol. OLSR finds nodes in order to send link-state information. Thus, Hello and Topology control messages are used. Individual nodes can check the topology information and then all of other nodes calculate the shortest path in order to send the data packets.

- DSR (Dynamic Source Routing) is a routing protocol for wireless mesh networks. The sender knows the complete hop-by-hop route to the destination. These routes are stored in a route cache. The data packets carry the source route in the packet header. The source node can make the RREQ packet and relays it in the network. Naturally, all neighbors near the source nodes can get the RREQ packets.

- Similarities: Both OLSR and DSR are the routing protocol for the mobile ad-hoc network (MANET). Therefore, the routing protocol algorithm manages propagation of the data packets.

- Differences: OLSR is a proactive (table-driven) routing algorithm. So, OLSR needs the routing table. When the routing table information is changed, the nodes should propagate changed routing table information to another nodes. Therefore, the nodes should frequently check the routing table information by using Hello and Topology control (TC) messages. An advantage is that it doesn't need the process to get the path when the path should be newly set. It would be good for small networks because time latency is low. However, DSR is a reactive routing algorithm, which is called on-demand. In other words, DSR carries out in an on-demand method. The RREQ packet is used in DSR. It would be good for the networks which should frequently move to another network. However, when it requires to get the path, all networks should be searched. Therefore, the latency is long.

3. What mobility models are included in ns-3?

- Base Class

- GetPosition()
- Position and Velocity attributes
- GetDistanceFrom()
- CourseChangeNotification

- Subclasses

- ConstantPosition
- ConstantVelocity
- ConstantAcceleration
- GaussMarkov
- Hierarchical
- RandomDirection2D
- RandomWalk2D
- RandomWaypoint
- SteadyStateRandomWaypoint
- Waypoint

In what directory are they located?

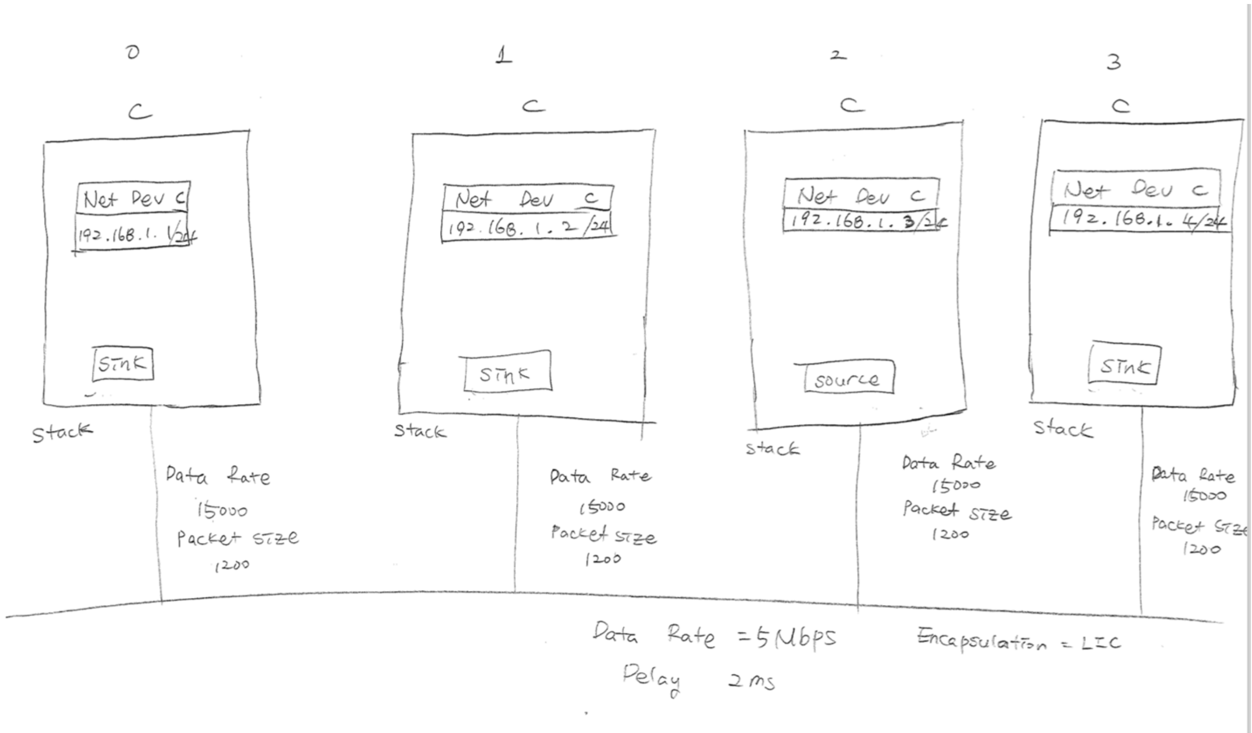
- ns-3-dev/src/mobility

Go on GoogleScholar and find one highly-cited paper on random waypoint mobility. List the paper title, authors, venue and year of publication.

- A survey of mobility models for ad hoc network research, Tracy Camp, Jeff Boleng, Vanessa Davies, Wireless communication and Mobile Computing, Aug/2002
- Random waypoint considered harmful, J. Yoon, M. Liu, B. Noble, IEEE INFOCOM, July/9th/2003
- The node distribution of the random waypoint mobility model for wireless ad hoc networks, C. Bettstetter, G. Resta, P. Santi, IEEE Transactions on Mobile Computing, Sep/23rd/2003

4. Who pings whom in this example?

- Node 0 can ping 1 and 3.
- Node 1 can ping node 0 and 2.
- Node 3 can ping node 0 and 1.
- However, node 2 can’t ping because the code opens only 3 sockets except for node 2.



1. How many of ICMP requests/replies were sent in each ping session?

In 1/csma-ping-0-0.pcap,

Source	Destination	Protocol	Length	Info
192.168.1.1	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.1	ICMP	110	Echo (ping) reply
192.168.1.1	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.1	ICMP	110	Echo (ping) reply
192.168.1.1	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.1	ICMP	110	Echo (ping) reply

1. Node 0 requests node 2 and node 2 replies back node 0
2. Node 0 requests node 2 and node 2 replies back node 0
3. Node 0 requests node 2 and node 2 replies back node 0

Therefore, **3 requests, and 3 replies.**

In 1/csma-ping-1-0.pcap,

Source	Destination	Protocol	Length	Info
192.168.1.2	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.2	ICMP	110	Echo (ping) reply
192.168.1.2	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.2	ICMP	110	Echo (ping) reply
192.168.1.2	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.2	ICMP	110	Echo (ping) reply

1. Node 1 requests node 2 and node 2 replies back node 1
2. Node 1 requests node 2 and node 2 replies back node 1
3. Node 1 requests node 2 and node 2 replies back node 1

Therefore, **3 requests, and 3 replies.**

In 1/csma-ping-2-0.pcap,

Source	Destination	Protocol	Length	Info
192.168.1.4	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.4	ICMP	110	Echo (ping) reply
192.168.1.1	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.1	ICMP	110	Echo (ping) reply
192.168.1.2	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.2	ICMP	110	Echo (ping) reply
192.168.1.1	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.1	ICMP	110	Echo (ping) reply
192.168.1.2	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.2	ICMP	110	Echo (ping) reply
192.168.1.4	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.4	ICMP	110	Echo (ping) reply
192.168.1.1	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.1	ICMP	110	Echo (ping) reply
192.168.1.2	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.2	ICMP	110	Echo (ping) reply
192.168.1.4	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.4	ICMP	110	Echo (ping) reply

1. Node 3 requests node 2 and node 2 replies back node 3.
2. Node 0 requests node 2 and node 2 replies back node 0
3. Node 1 requests node 2 and node 2 replies back node 1
4. Node 0 requests node 2 and node 2 replies back node 0
5. Node 1 requests node 2 and node 2 replies back node 1
6. Node 3 requests node 2 and node 2 replies back node 3
7. Node 0 requests node 2 and node 2 replies back node 0
8. Node 1 requests node 2 and node 2 replies back node 1
9. Node 3 requests node 2 and node 2 replies back node 3

In conclusion, it has **9 requests and 9 replies.**
P.S. Even though there are 9 requests and 9 replies, the actual number of requests and replies are 3, which means that there are 3 requests and 3 replies. This is because that only 3 requests and 3 replies show the round trip time. The rest of requests and replies have 0.0.

In 1/csma-ping-3-0.pcap,

Source	Destination	Protocol	Length	Info
192.168.1.4	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.4	ICMP	110	Echo (ping) reply
192.168.1.4	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.4	ICMP	110	Echo (ping) reply
192.168.1.4	192.168.1.3	ICMP	110	Echo (ping) request
192.168.1.3	192.168.1.4	ICMP	110	Echo (ping) reply

1. Node 3 requests node 2 and Node 2 replies back Node 4
2. Node 3 requests node 2 and Node 2 replies back Node 4
3. Node 3 requests node 2 and Node 2 replies back Node 4

Therefore, **3 requests, and 3 replies.**

2. Did you notice any protocols that were not ICMP-related? Why were they necessary?

- ARP: ARP stands for Address Resolution Protocol. This protocol is used for mapping the network address, like IPv4, to the the physical address like the MAC address. Therefore, ARP is necessary.
- IGMPv0: IGMP stands for Internet Group Management Protocol. This protocol is used by the host and adjacent routers on IPv4 networks. The protocol can make the multicast groups. Therefore, the protocol is necessary.

3. Were there any packet losses?

- No, there weren't any packet losses

4. Compare and contrast RTTs achieved in simulation to these from real-world measurements. Comment on your findings.

- See attached files for simulation RTTs
- Real world RTTs are way longer than NS-3 RTTs. In addition, real world measurements show packet losses.

wooseok — -bash — 80×24

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64 bytes from 74.125.21.105: icmp_seq=97 ttl=45 time=45.924 ms
64 bytes from 74.125.21.105: icmp_seq=98 ttl=45 time=106.839 ms
64 bytes from 74.125.21.105: icmp_seq=99 ttl=45 time=43.873 ms

--- www.google.com ping statistics ---
100 packets transmitted, 96 packets received, 4.0% packet loss
round-trip min/avg/max/stddev = 42.872/84.772/582.456/91.447 ms
Wooseoks-MBP:~ wooseok$ ping www.google.com -c 10
PING www.google.com (74.125.21.105): 56 data bytes
64 bytes from 74.125.21.105: icmp_seq=0 ttl=45 time=44.103 ms
64 bytes from 74.125.21.105: icmp_seq=1 ttl=45 time=107.311 ms
64 bytes from 74.125.21.105: icmp_seq=2 ttl=45 time=68.104 ms
64 bytes from 74.125.21.105: icmp_seq=3 ttl=45 time=59.725 ms
64 bytes from 74.125.21.105: icmp_seq=4 ttl=45 time=54.019 ms
64 bytes from 74.125.21.105: icmp_seq=5 ttl=45 time=94.856 ms
64 bytes from 74.125.21.105: icmp_seq=6 ttl=45 time=44.591 ms
64 bytes from 74.125.21.105: icmp_seq=7 ttl=45 time=46.050 ms
64 bytes from 74.125.21.105: icmp_seq=8 ttl=45 time=70.385 ms
64 bytes from 74.125.21.105: icmp_seq=9 ttl=45 time=44.753 ms

--- www.google.com ping statistics ---
10 packets transmitted, 10 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 44.103/63.390/107.311/21.130 ms
Wooseoks-MBP:~ wooseok$
```