LL SimpleWireless: A Controlled MAC/PHY Wireless Model to Enable Network Protocol Research

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Outline

- Introduction
- SimpleWireless Model
- LL SimpleWireless Model Features
  - Error Models
  - Packet Queueing
  - Transmission Delay
  - Fixed Contention
  - Simulated Directional Networks
  - PCAP Packet Capture
- Evaluation
- Future Work

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Introduction

- **Network protocol research warrants a controlled wireless environment**
  - **Example: testing a new routing protocol user may initially want a controlled environment with limited delay and guaranteed delivery**
- **Existing ns-3 wireless models are not designed for such use**
  - **WiFi**
    - **Limited transmission range**
    - **Does not support large number of nodes**
    - **Must configure many parameters that affect network performance**
  - **WiMax:**
    - **Improvements over WiFi**
    - **Still required to configure many parameters that affect network performance**

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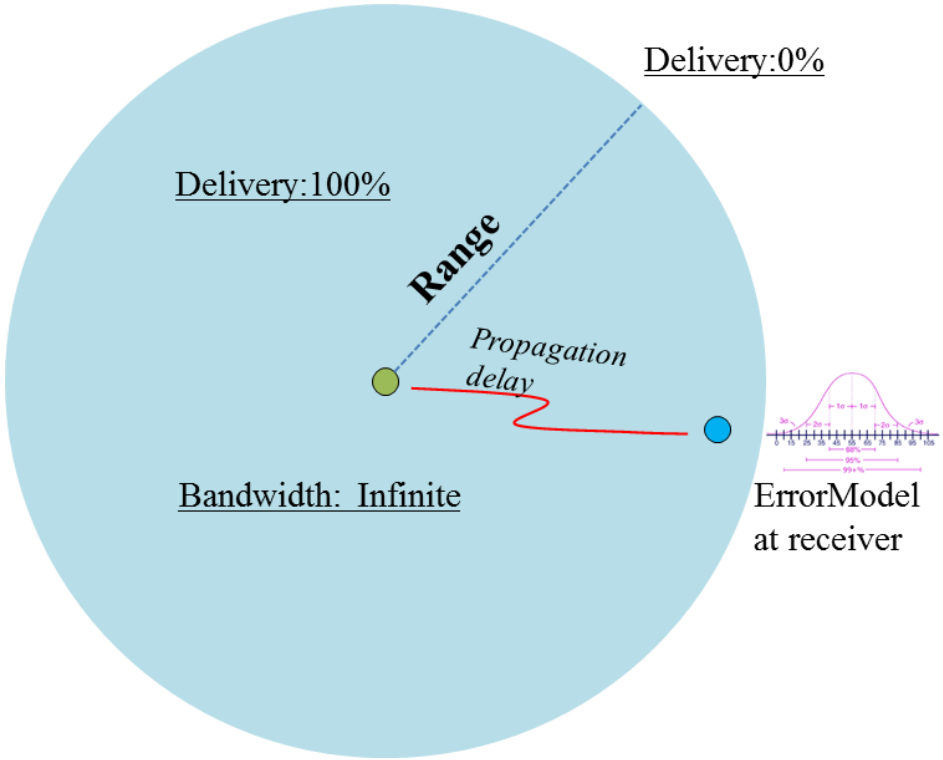
SimpleWireless Model

- **Simple Wireless Model**
  - **Available as an add-on to ns3***
  - **Range based on/off for packet transmission**
  - **Not based on any specific protocol**
- **Features:**
  - **Infinite Bandwidth**
  - **Packet delivery is all or nothing based on range**
  - **Propagation delay only**
  - **ErrorModel at receiver**



If there are 1000 destinations in range, they all receive the data perfectly and nearly simultaneously

*SimpleWireless model available at `http://code.nsnam.org/tomh/ns-3-simple-wireless`

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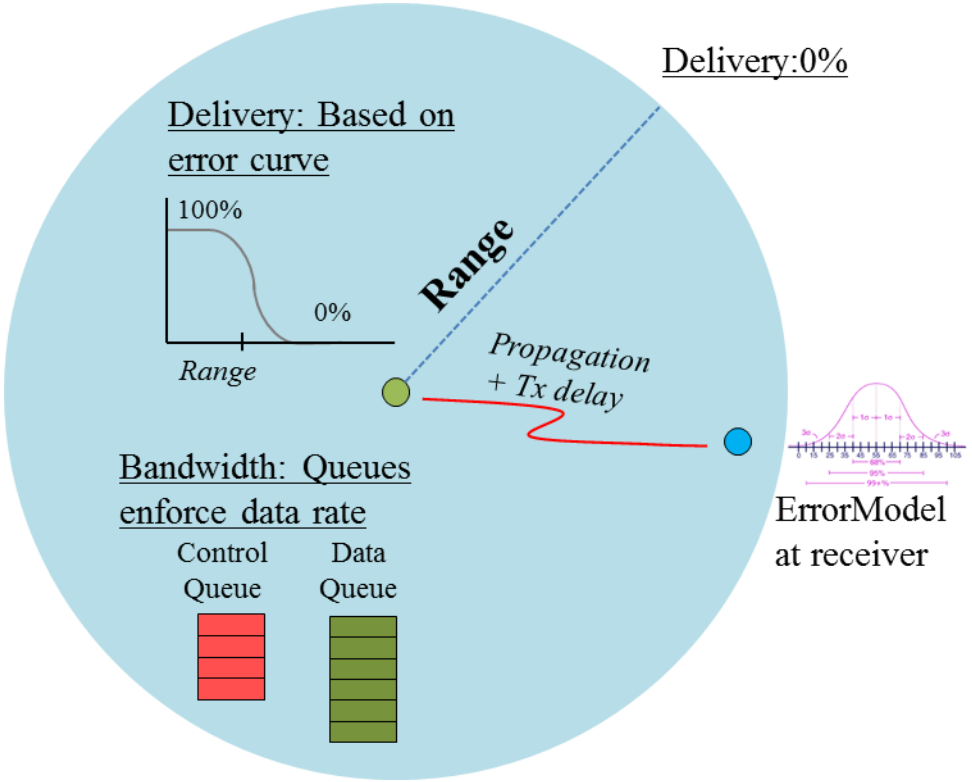
LL SimpleWireless

Adds features to SimpleWireless:

- **Send side Error Models (including range based)**
- **Packet Queueing**
- **Fixed Contention**
- **Directional Network Support**
- **Transmission Delay**
- **PCAP Packet Capture Support**



➢ ***All features except transmission delay are optional and do not have to be enabled.***

Error Models

- Implemented on the send side
  - Reduces simulation overhead
  - Packets that would not arrive at destination are not sent so packets are deleted earlier in processing chain
- Three models added:
  1. Constant Error Rate
  2. Packet Error Rate Curve
  3. Stochastic

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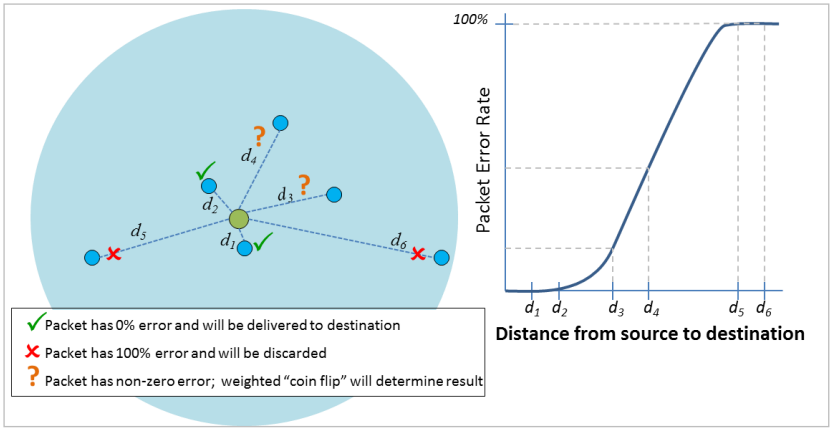
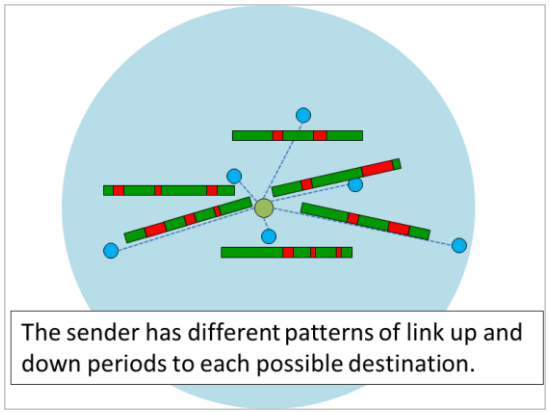
Error Models (con't)

- **Constant Error Rate**
  - applies a uniform random distribution
  - Limited capabilities but provides easy method for send side packet dropping
- **Packet Error Rate Curve**
  - Applies user defined curve for distance versus error
  - Sender uses distance to determine the packet error rate based on user-defined PER curve
- **Stochastic Error**
  - Channel based not packet based
  - Two distributions (up and down) used to toggle state of channel per destination

Packet Error Rate Curve



Stochastic Error



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Packet Queueing

- **Provides support for data rate on the device**
- **All queues are FIFO**
- **Dropping packets when full user selectable (drop head or tail)**
- **Priority queues available to separate control and data traffic**
  - **PCAP string filter used to distinguish control vs. data**
  - **Control queue always serviced first**
- **Busy state is maintained at the device**
  - **Device state is set to busy when a packet is sent by the device *without consideration* to what happens at the channel**
  - **If a packet is dropped at the channel based on Error Model, the device remains busy**
    - Error models on send side do not affect the data rate

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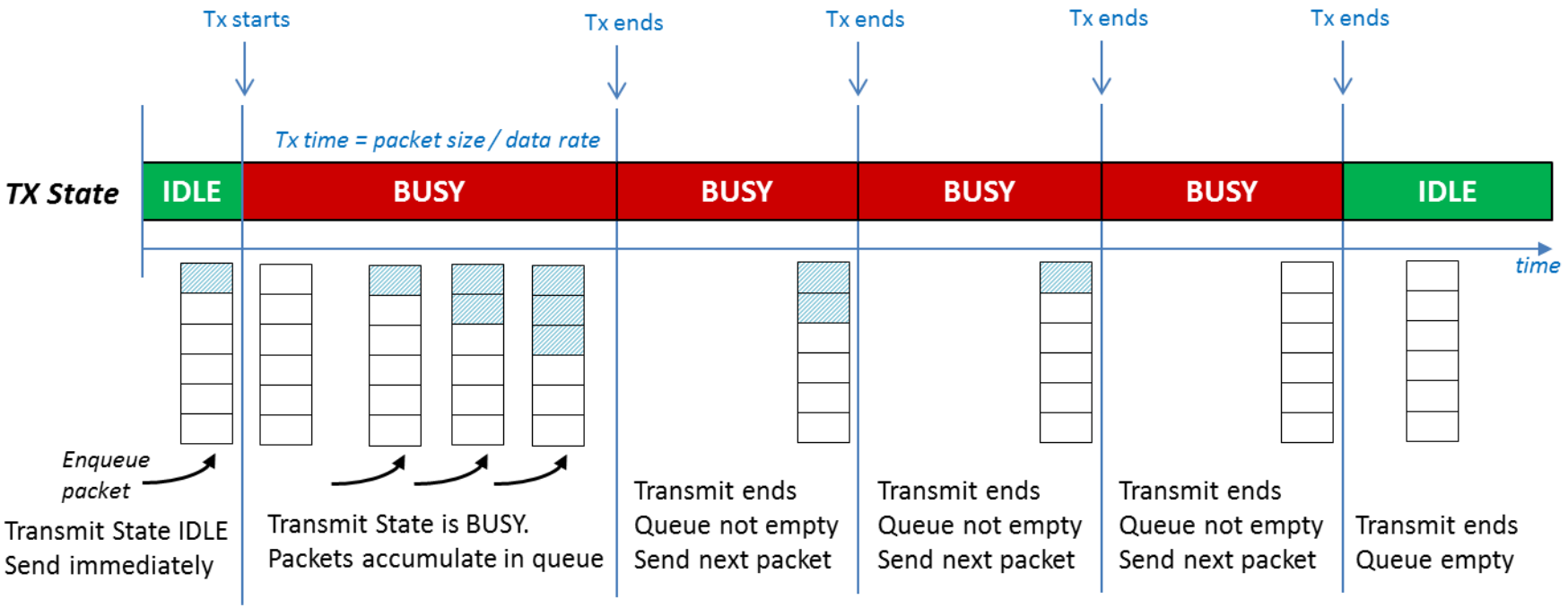
Packet Queueing



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Transmission Delay

- Packet Size / Device Data Rate
- Only feature which can not be disabled
  - Effectively “disable” by setting device data rate to a very high value making the transmission delay very small

PCAP Packet Capture

- Feature exists on other ns-3 device models
- Added to LLSW for consistency with other ns-3 models

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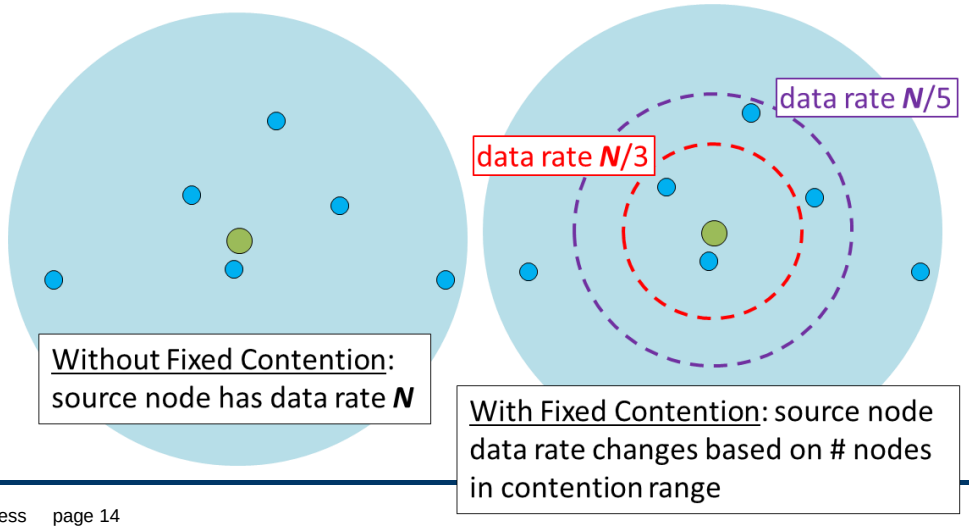
Fixed Contention

- **Simulates sharing of the channel among neighbors**
  - **Queues enforce data rate at each node separately but in reality bandwidth must be shared, i.e., each node does not necessarily get 100% of bandwidth**
- **Adjusts data rate based on number of neighbors in user configurable "contention" range**
  - **Adjusted Data Rate = Data Rate / # neighbors**



Caveat: Best used in scenarios with high volume traffic because that is when the full number of neighbor nodes would actually cause contention.
When the volume of traffic is low and nodes are able to transmit when no other neighbor is transmitting, this contention model would falsely reduce the data rate as though the transmissions were contested when in fact they were not.

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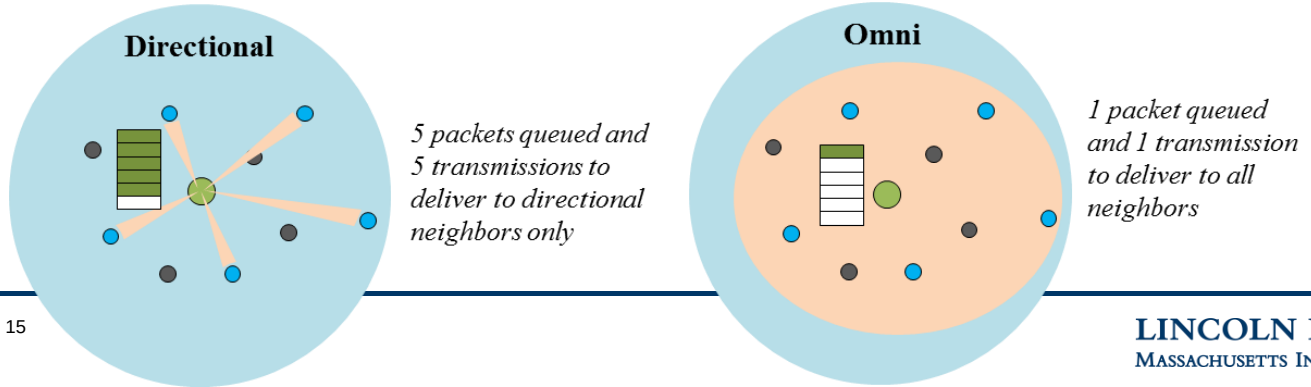
Simulated Directional Networks

- **Simple directional network based on user defined neighbor list for each node**
  - **Neighbor list is statically configured as part of scenario**
  - **LLSW provides functions to update the list dynamically but does not provide features to automatically manage the list**
- **Causes multiple packets to be queued (one for each node in the neighbor list)**
- **Packets are transmitted serially**
  - **LLSW assumes a single radio so transmission is serial**



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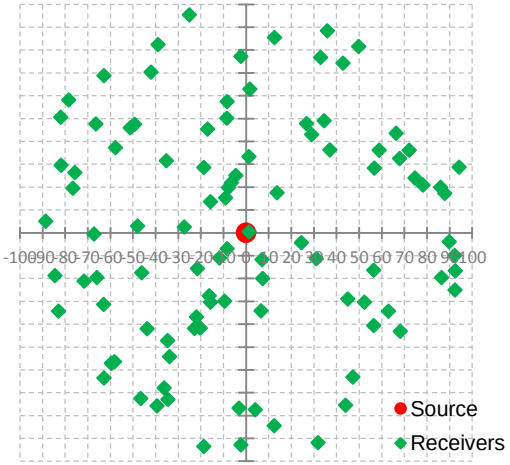
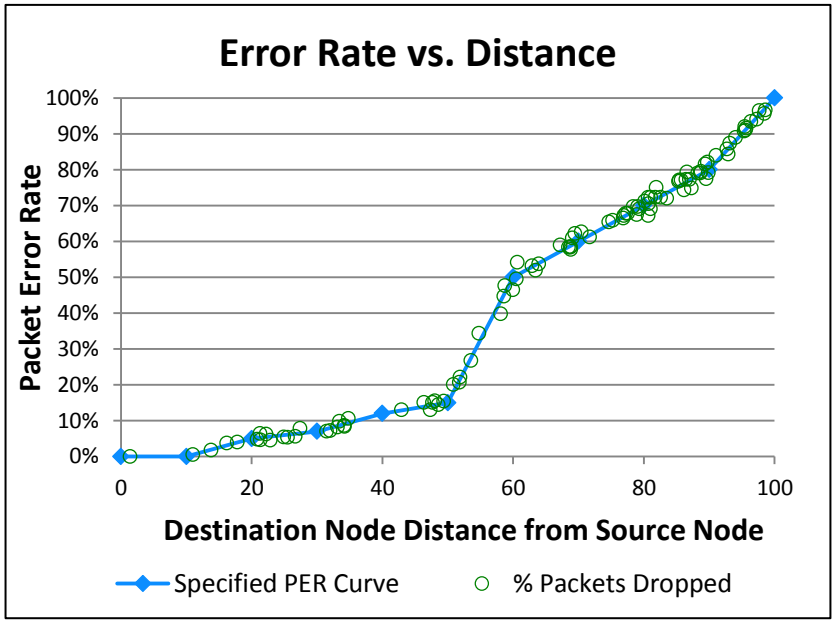
Evaluation

- **Each new feature was evaluated for correct behavior and performance**
- **Error Model**
  - **101 nodes on 100x100 area**
  - **Node 0 at (0,0) transmits 1Mbps**
  - **Nodes 1-100 randomly placed**
  - **PER curve applied**



- **Measured packet error rate matches the specified PER curve**



Results for testing of Fixed Contention with this same scenario are shown in the paper

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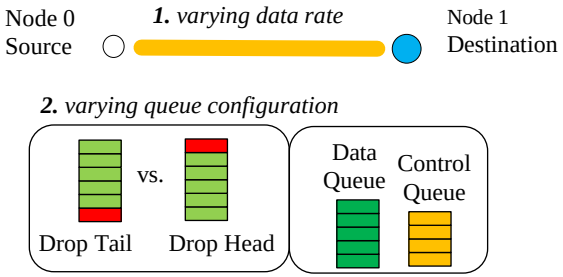
- **Queues**

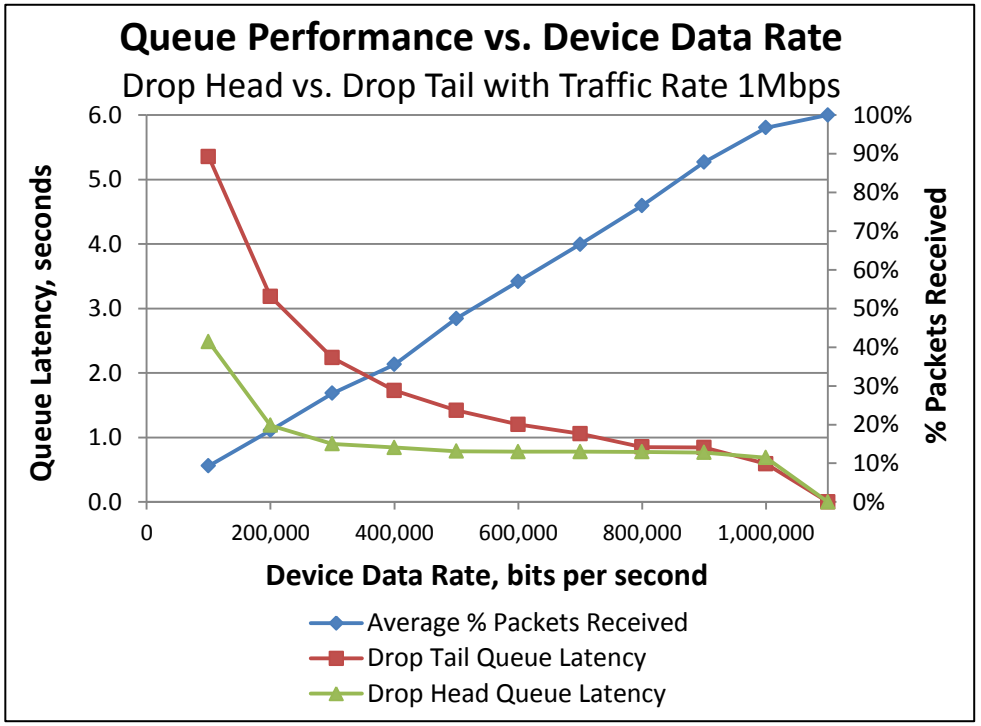
- 2 nodes
- Node 0 transmits data at 1Mbps
- Vary:
  1. Data Rate of device
  2. Queue Configuration



Drop Head vs. Drop Tail

- Delivery Rate increases as device data rate increases
- Drop Tail Queue has higher latency

NOTE: Not 100% delivery at 1Mpbs device data rate because of routing traffic



Similar results for testing with Control vs. Data queues are shown in the paper

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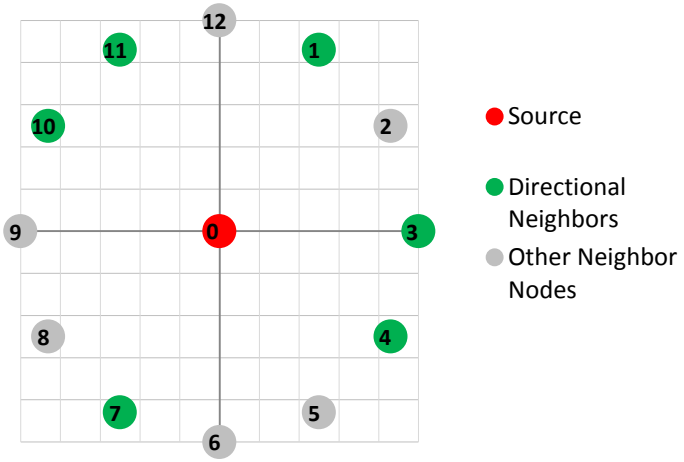
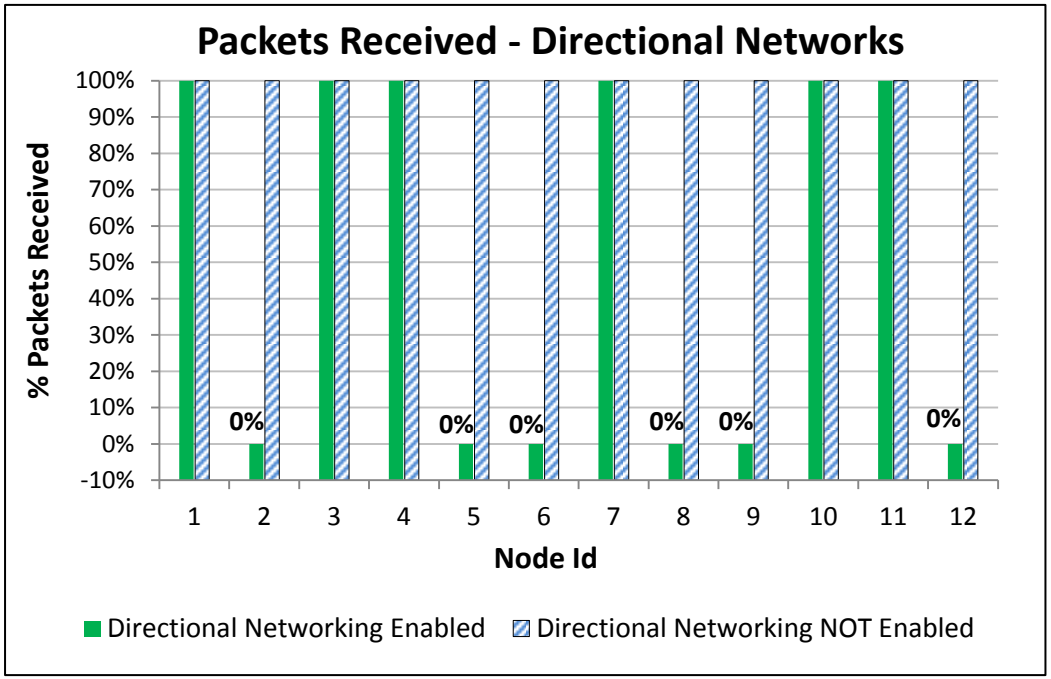
- **Directional Networks**

- 13 nodes
- Node 0 at (0,0) transmits 1Mbps
- Nodes 1-12 placed at perimeter of circle in clockwise manner
- Node 0 has 6 directional neighbors



- When directional networking is enabled, only the 6 specific neighbors receive traffic
- When disabled, all nodes receive traffic



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Future Work

- **Add full ErrorModel support on send side**
- **Add support to queues for user configurable sub-queues**
  - Only supports 1 queue for all packets or 2 sub-queues for control and data
  - Expand to allow user configuration to N sub-queues which use PCAP string filter
- **Add support for distance based data rate**
  - Would allow for simulation of adaptive coding techniques
- **Add support for multiple radios in directional network feature**
  - Would allow simultaneous transmissions instead of serial
- **Add support for automatic neighbor list updates based on mobility for directional network feature**
- **Add support for interference**

LL SimpleWireless

- **Available at MIT Lincoln Laboratory GIT HUB:**
  - **https://github.com/mit-ll/LL-SimpleWireless**
  - **GPLv2 license**
- **Package includes documentation, examples (including evaluation scenarios) and model source code**

ll-simple-wireless/:
```
/doc
/examples
/model
wscript
README
```

ll-simple-wireless/doc:
```
simple-wireless.rst
```

ll-simple-wireless/examples:
```
directional_test.cc
error_model_test.cc
fixed_contention_test.cc
mixed_directional_network.cc
multiple_interface_example.cc
queue_test.cc
wscript
```

ll-simple-wireless/model:
```
drop-head-queue.cc
drop-head-queue.h
priority-queue.cc
priority-queue.h
simple-wireless-channel.cc
simple-wireless-channel.h
simple-wireless-net-device.cc
simple-wireless-net-device.h
```

Conclusion

- **LL SimpleWireless model provides a simple, configurable MAC layer model for ns-3**
- **Advantages over existing models (WiFi and WiMax) for network protocol research**
- **Model released and available for public use**