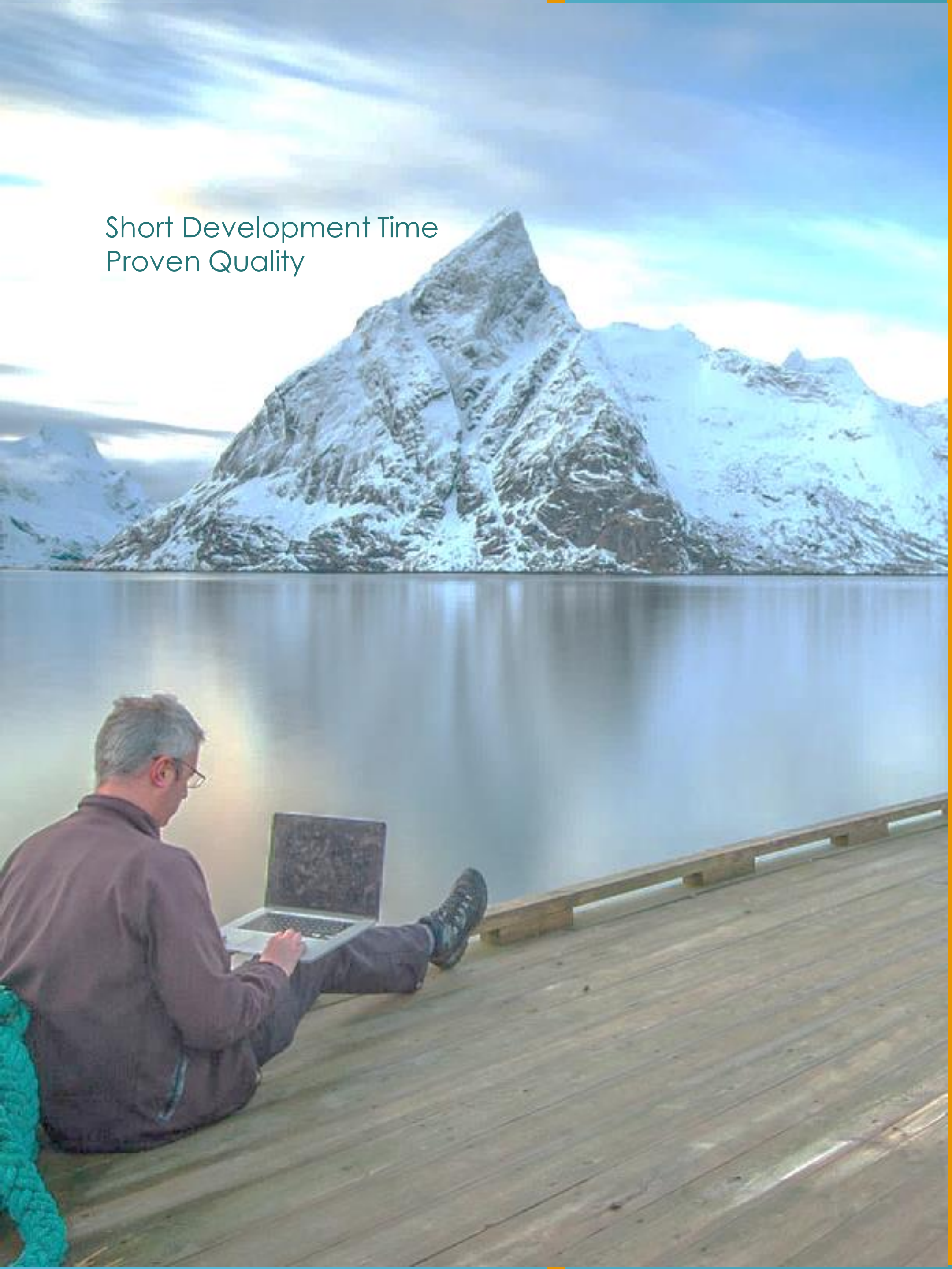

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Presentation will start shortly….

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RIIM for Smart Street Lighting Networks:
Simulations Results
April, 2020

RIIM for Smart Street Lighting Networks: Simulations Results

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April 2020

- Omar Khalil, Applications Engineer

House-keeping

- The webinar today is scheduled for 30 minutes with a 10-15 minutes Q&A afterwards.
- Please introduce yourselves in the chat window, so we know who is listening
- Post your questions in the chat window during the webinar, and we will answer the best we can in the Q&A session.
- We will post a recorded version of the webinar on our website after it's over, in case you want to go back and see it again.

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Agenda

- Introduction to smart street lighting & key drivers in the market
- Challenges in implementing smart street lighting networks
- Cellular LPWAN? Star topology networks? Why mesh is the best?
- Quick re-cap about RIIM
- Simulation results

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Importance of Smart Street Lighting

- Street lighting accounts for around 19% of global electricity usage.
- Street lighting is responsible for around 40% of a city's electricity expenditure.
- Very environmentally unfriendly, especially with growing concerns over climate change due to CO2 emissions.
- According to UN, 68% of the total world population will live in urban areas by 2050. This puts great demand on smart street lighting solutions.

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Benefits of Smart Street Lighting

- Automatic lighting setting
- Customized lighting intensity
- Increased nighttime visibility
- Reduces light spillage into residential apartments
- Centralized control and management systems

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Challenges of Implementing Street Lighting

- Three main technologies involved:
  - RF Technologies
  - Management Center Technologies
  - Lighting Technologies
- Not all were mature enough to encourage investors

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Challenges of Implementing Street Lighting

- RF Technologies
  - Huge advancements made in the RF domain
  - Lower cost of hardware
  - More options in license-free bands

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Challenges of Implementing Street Lighting

- Management Center Technologies
  - Database systems and local servers become more abundant and secure
  - Rise of cloud solutions
  - Wide variety of data-visualization tools available

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Challenges of Implementing Street Lighting

- Lighting Technologies
    - Most used in the past were the HID (high intensity discharge) mercury vapor and the sodium halide bulbs
    - LED offers a 52% reduction in energy usage over HID
    - LED offers 26% reduction over sodium halide bulbs

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Possible connectivity solutions

Cellular LPWANs

- NB-IoT (Narrowband IoT) and LTE CAT-M1 (LTE Category M1)
- Subscription fee per device
- 100% Availability is extremely unlikely
- Very fast-paced technological advancement

Proprietary LPWANs

- Star topologies?
- LoRa
- Sigfox
- Optimized for UL
- All nodes have to be in direct connection with gateway
- Not very dynamic

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Possible connectivity solutions

- Why are mesh networks, by far, the most commonly used networks in smart street lighting solutions?

- Mesh Topology Networks
  - Dynamic and versatile network architecture
  - All light poles will have to have direct connectivity to the gateway
  - Each node can communicate to at least 2 or 3 light poles in one direction
  - Creates redundancy and avoids single points of failure in the network
  - Data is routed through the mesh structure, up and down the network, by hopping from one router to the other.

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An IIoT Wireless IP mesh network in a module

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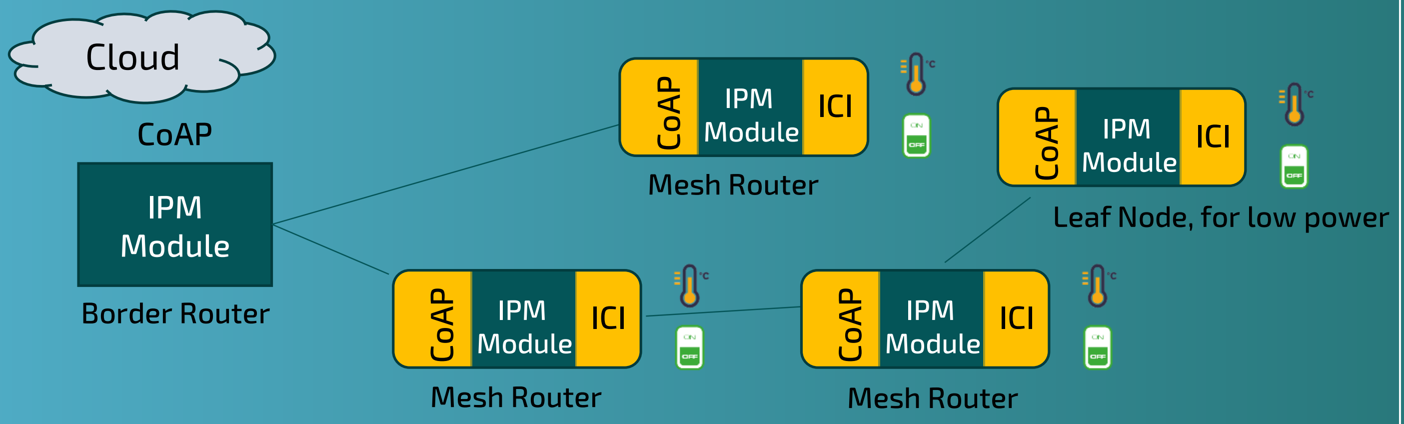
Developed for you to easily create your own industrial grade access network with direct IP connectivity



- Self forming / Self healing mesh
- Connects:
  - any sensors
  - any controllers
- No license fee
- No subscription
- Long Range RF
  - 40 x 40 km coverage
  - 915 / 868 MHz
- 50 kbps data-rate
- Pre-certified

The IPM Module is the core of the network nodes and supports the complete RIIM network. The IPM module can be configured as border router, mesh router or leaf node.

Each Node has a CoAP client/server to provide IP level access

A complete Border Router boxed product with Ethernet interface is available from Radiocrafts

Development by the customer:

- Sensor/Controller chips and interfaces
- Sensor/Controller data formatting & data processing
- PCB and power
- Enclosure

Time Synchronized/Slotted Channels (TSCH)

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- Nodes form a globally synchronized network
- The network broadcasts beacons which contain timing information to let other nodes synchronize and join
- The airtime is divided into a continuously repeated set of slots and a node is only allowed to communicate during its assigned slot(s)
- Child nodes continuously correct their relative clock drift to their parent through timing information in acknowledgement packets
- Nodes can sleep most of the time and only wake up during their assigned slots, and RF interference is mitigated through channel hopping.
    - Higher resilience to RF interference
    - Higher network reliability
    - Enabling battery-operated Mesh Routers
    - Enabling frequency hopping, which is a requirement for FCC certification to enter the US market

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Benefits of Using RIIM in Street Lighting

- RIIM Supports 28 hops
- Faulty Node detection
- Multicasting feature can be used to send a broadcast message to all nodes at the same time with new lighting schedules
- RIIM modules with ICI support are Over The Air (OTA) upgradable
- Multiple frequency bands support for various regions

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Short Development Time
Proven Quality

Importance of Multicasting

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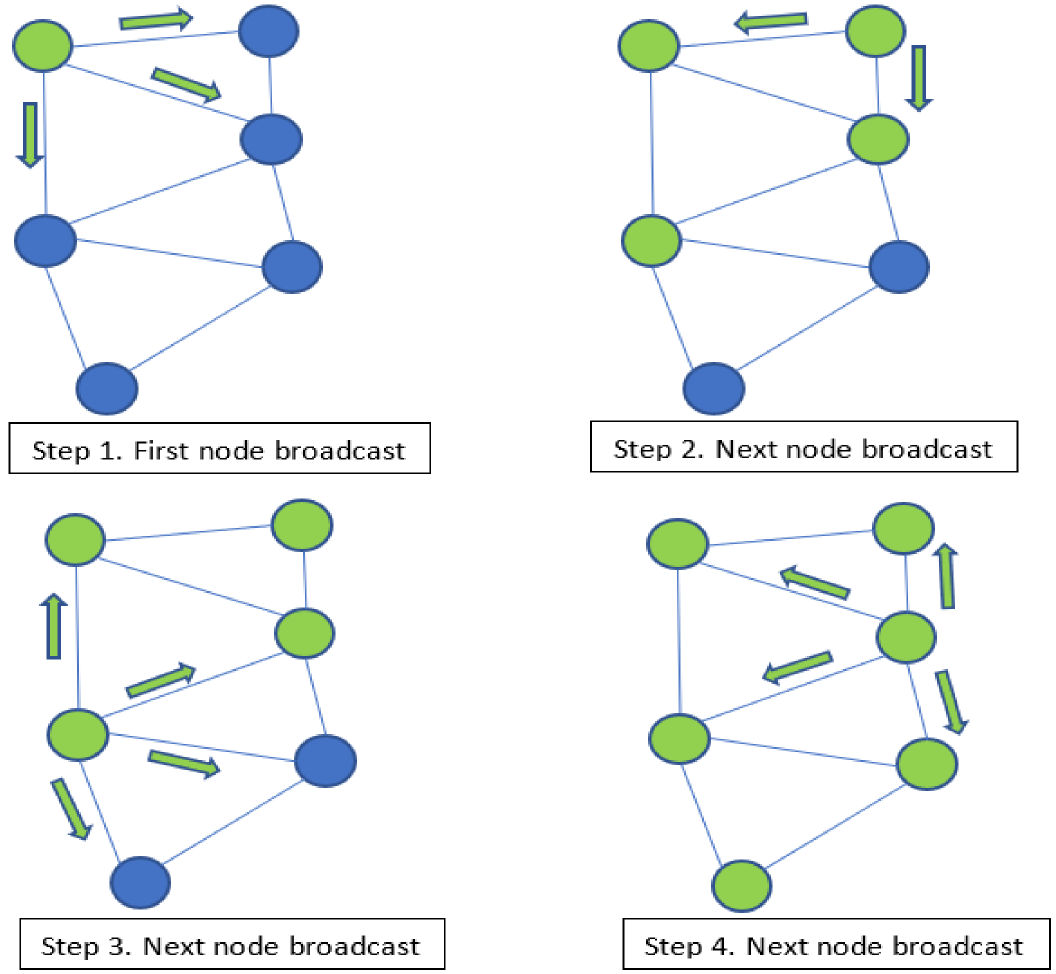

Figure 2 Flooding concept

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Importance of Multicasting

- MPL-Multicasting for Lossy Low-Power Networks
    - Proactive forwarding
    - MPL control packets sent regularly between nodes
    - These packets compare how many multicast messages each node has received from a given node
    - If one node has received more messages than its neighbor, then the missing messages are sent to that node
    - Nodes must be able to save messages

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Benefits of Simulations

- Why do we simulate?
  - How many nodes?
  - What's the logical topology?
  - What's the network density?
  - How will the traffic pattern be?
  - What are the key parameters a user can tweak to fine tune his network's behavior?

Simulations Results

- Two use-case scenarios simulated:
- Case 1:
  - 100 nodes
  - 4 km street, straight line
  - 40 m in average between light poles
  - Broadcast messages sent every 4 hours
  - Sensor reading from each pole every 2 hours
  - Assumed maximum range of communication for each pole is 200 m (Range in reality can be higher)

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Simulations Results

- Two use-case scenarios simulated:
- Case 2: In addition to the 100 nodes simulated, we added more nodes to make the network reach up to 450 nodes
- We are working up to 1000 nodes!

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Simulations Results, Case 1

- Network Formation
  - A network with 100 nodes, with all the network formation and rerouting packets being sent, took only 6 minutes to be formed, of course, automatically, without any configuration or setting needed from the user
  - For case 2, we have simulated for 450 nodes, and we found out that the time needed to form the network formation was always still around 6 mins.
  - We believe the reason why the network formation time doesn't scale up with the number of nodes is that it is given by the longest hop-chain.

Simulations Results, Case 1

- Network Logical Topology
  - Figure shows the logical topology of the network.
  - The furthest and most remote node in this network is 20 hops away from the Border Router.
  - In some cases, the best route for a node was to connect to the string in a straight line manner, and in other situations it was best for a node to form a little mesh at some points with only of the nodes of that little mesh laying on the main string.
  - Just because the nodes are on a straight line physically, it doesn't mean that the logical topology will be the same.

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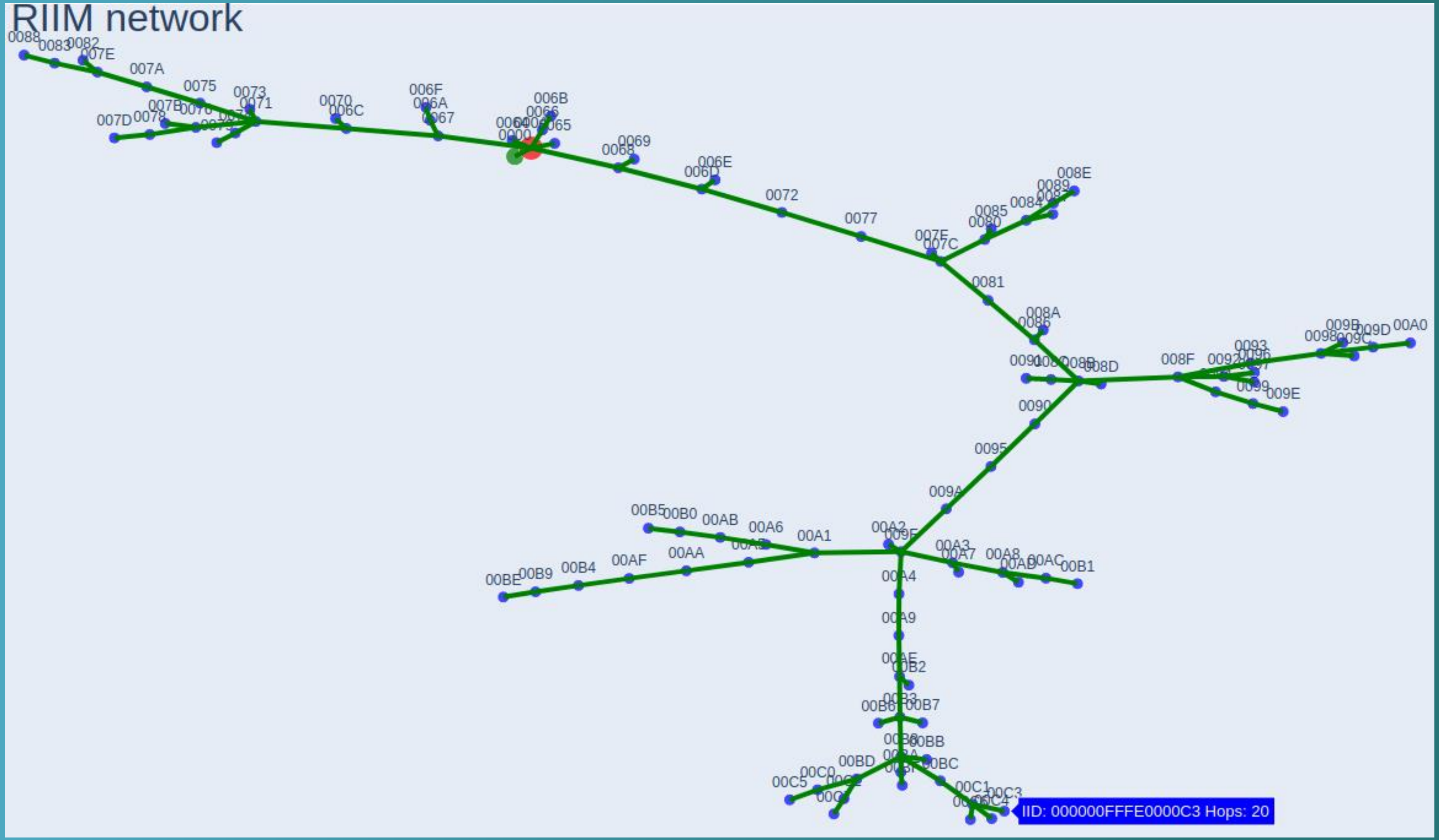
Simulations Results, Case 1

- Network Logical Topology



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Simulations Results, Case 1

- Packets Frequency
  - During the time of the simulation, a total of 514749 packets were sent on air in 86382 seconds
  - Which is equivalent to 24 hours.
  - This equals about 6 packets/second being sent in the network
  - Out of these 514749 packets, 251000 are MAC ACKs (Acknowledgments)
  - On a single node level, a randomly picked node, in this case it was node number 75 which is 3000m away from the Border Router, was found to have sent 1731 packets (not counting ACKs) in the same amount of time. This equals 0.02 packets / second = 50 seconds between packets
  - Border router sends 5859 (counting ACKs) in the same times period. This is 0.07 packets per second = 15 seconds between packets.

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Simulations Results, Case 1

- Multicast Latency
  - 5 multicast messages were sent from the Border Router to the nodes.
  - The average time observed for the 5 multicast messages was 31.4 seconds
  - Multicast latency (msg: "MCast 100"): 32496
  - Multicast latency (msg: "MCast 101"): 31186
  - Multicast latency (msg: "MCast 102"): 28742
  - Multicast latency (msg: "MCast 103"): 33996
  - Multicast latency (msg: "MCast 104"): 30789
- For Case 2, the average Multicast latency observed was around 27 seconds in average for networks up to 450 nodes.

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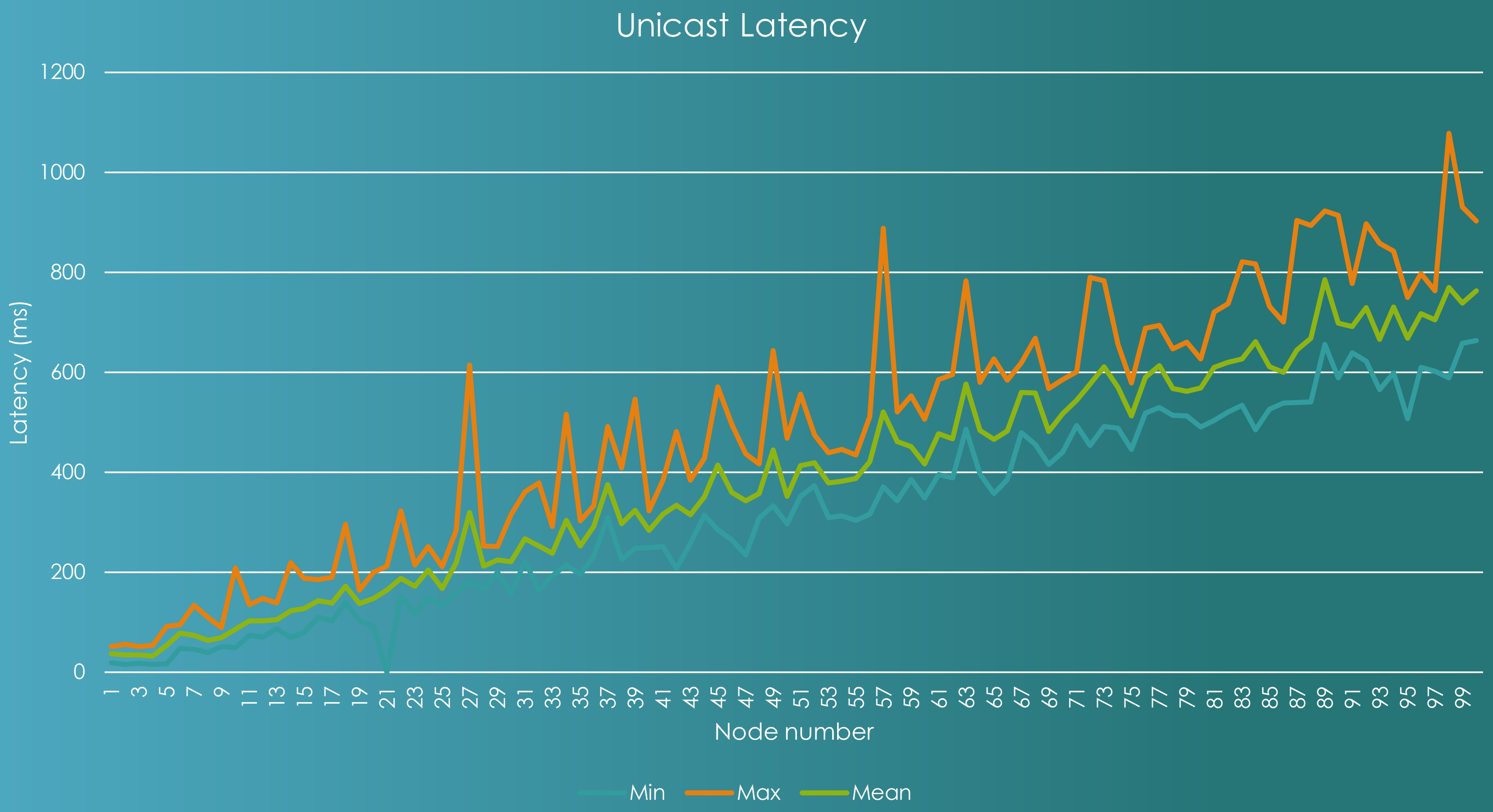
Simulations Results, Case 1

- Unicast Latency
  - Unicast messages were sent every 2 hours



Q&A

- Any questions?

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Read more on RIIM

https://radiocrafts.com/products/riim-network/

Thank you for your attention!