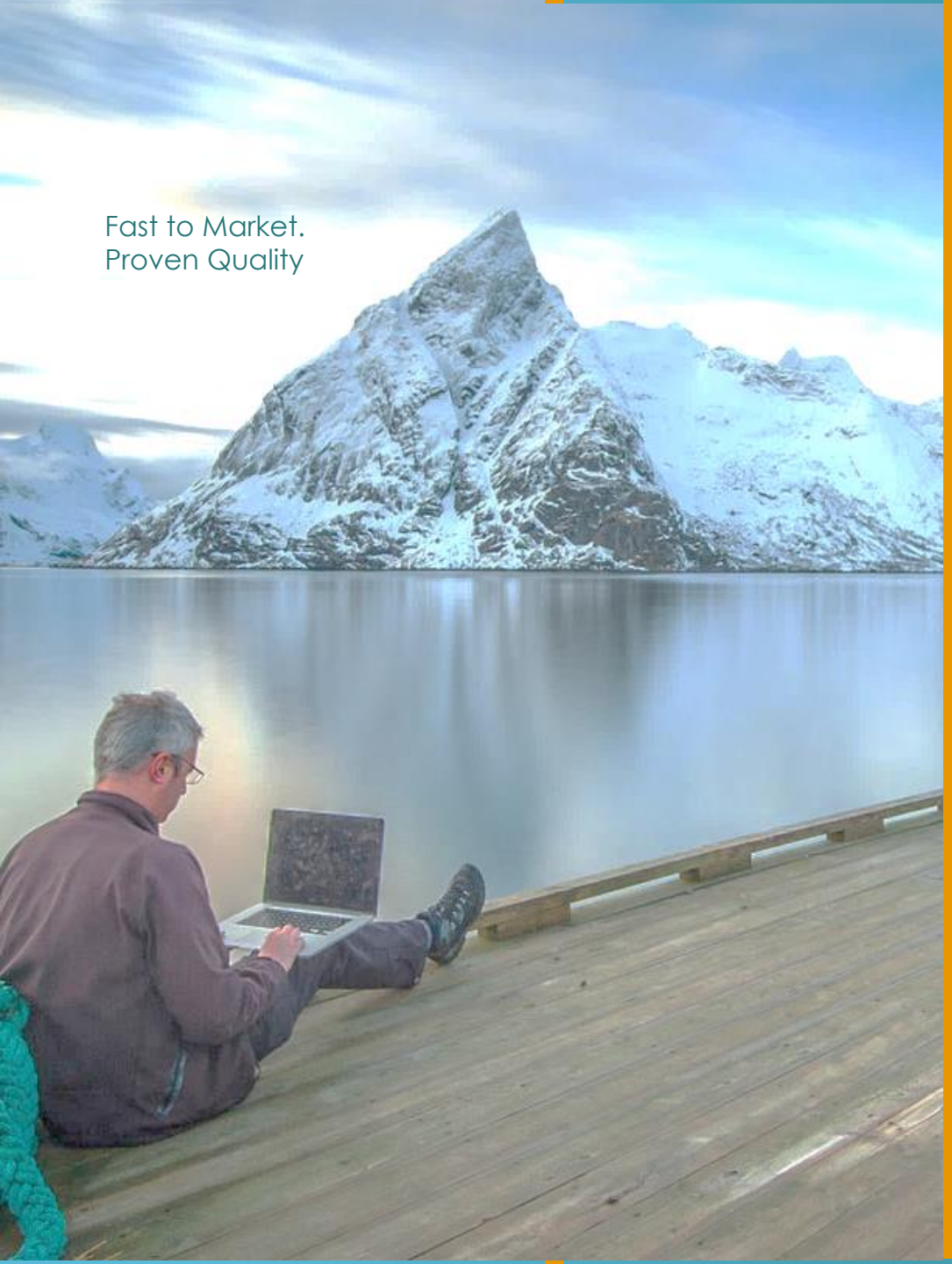

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Presentation will start shortly….

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How to Actualize A Long Range Wireless Network With Many Sensors
May, 2019

How to Actualize A Long Range Wireless Network With Many Sensors

- Anders Oldebäck, S&M Director
- Nicholas Nytun, S&M Coordinator

House-keeping

- The seminar 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 seminar, and we will answer the best we can in the Q&A session.
- We will share the presentation after the webinar to the attendees. and we will post it on the web.

Why are many nodes in long range wireless networks an issue

1) The available frequency spectrum is limited and output power is limited due to regulatory limitations

2) Long range → High sensitivity → Low data-rate
Long packet transmission times

3) Long packet transmission times

How many nodes are “High node count” ?

Well, like almost always in radio communication, it depends…..

For the purpose of this presentation then it is the number of nodes per gateway/base-station

- 1-10 is low node count, should not be a problem for most wireless system
- 10-100 here is where some networks start to have issues, so you need check the ability to support your network design with respect to node count, not to fall into a trap.
- 100-1000 here is where you do need to pay attention and have the node count as an important decision factor
- Over 1000, only a few networks supports over 1000. such networks are needs to be design at start to support high node count.

Competing nodes

All nodes competes for the same spectrum band

A transmitter will broadcast occupying a certain frequency range

Only one device (the loudest) can be listened to at any one time in that particular frequency range

It is like you can only listen actively to one person at a time in a room where several persons are talking

So you need to manage the persons talking, if you want to listen to many

We will discuss today some concerns, solutions and recommendations regarding high node count for LPWANs

1. Radio performance (selectivity)
2. Transmission packet length
3. Packet transmission rate
4. MAC, Media Access Control
5. Regulatory requirements

Selectivity, don't listen to everyone

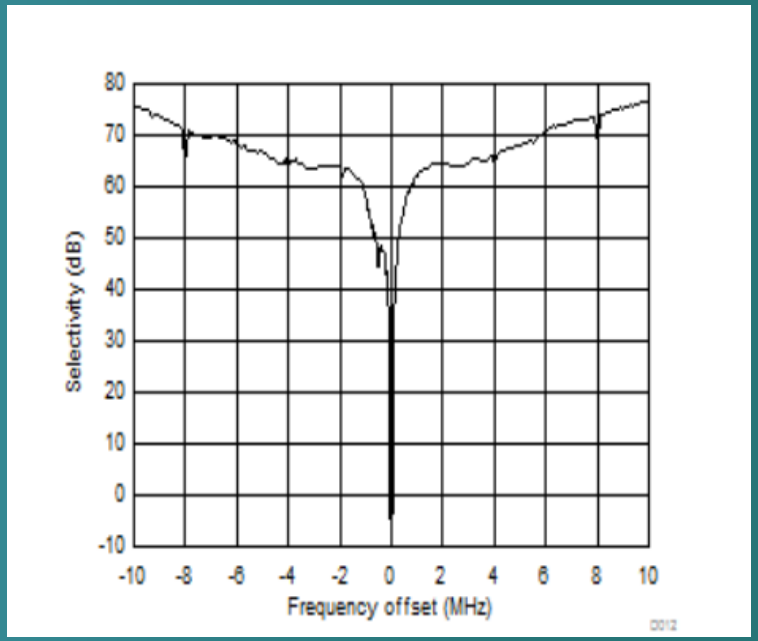
Selectivity: the ability of a device to respond to a particular frequency without interference from others

This is a key parameter for a Radio receiver and is a measure of how much radio traffic on nearby channel that the receiver can tolerate, while still receiving data on the intended channel

A high number of the Selectivity, close to the wanted frequency, compared to the number at the desired frequency is good.

Selectivity is determined by the filter on the input of the radio receiver

Any high node count radio network needs receivers with good selectivity



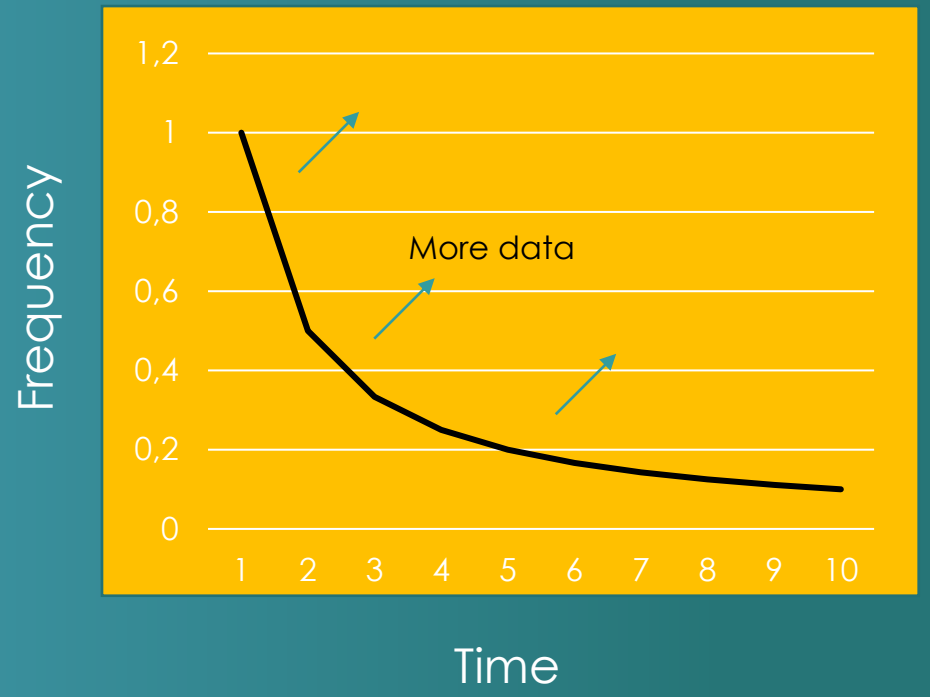
Transmission packet length background

To have many nodes, then each node needs to transmit under a relatively short time (the nodes take turns) and occupy a small frequency range (they occupy a small part of the spectrum)

Concern: Short time means high frequency and vice versa, given that the amount of data is the same
T = 1/f (T=period, f=frequency)

The same amount of data will either take long time or require a high frequency

More data will move the line up to the right, i.e increase one or both of time and frequency



Transmission packet length

To have long reach, then a high sensitivity is needed. I.e ensure that a the lowest possible signal level can be detected

$\mathbf{S_{min}} = (S/N)_{min} kT_o \mathbf{B} (NF) G$ (formula for the lowest signal level that can be detected, S_{min})

S/N_{min} = Minimum signal-to-noise ratio needed to process (vice just detect) a signal
NF = Noise figure/factor

k = Boltzmann's Constant = 1.38×10^{-23} Joule/°K

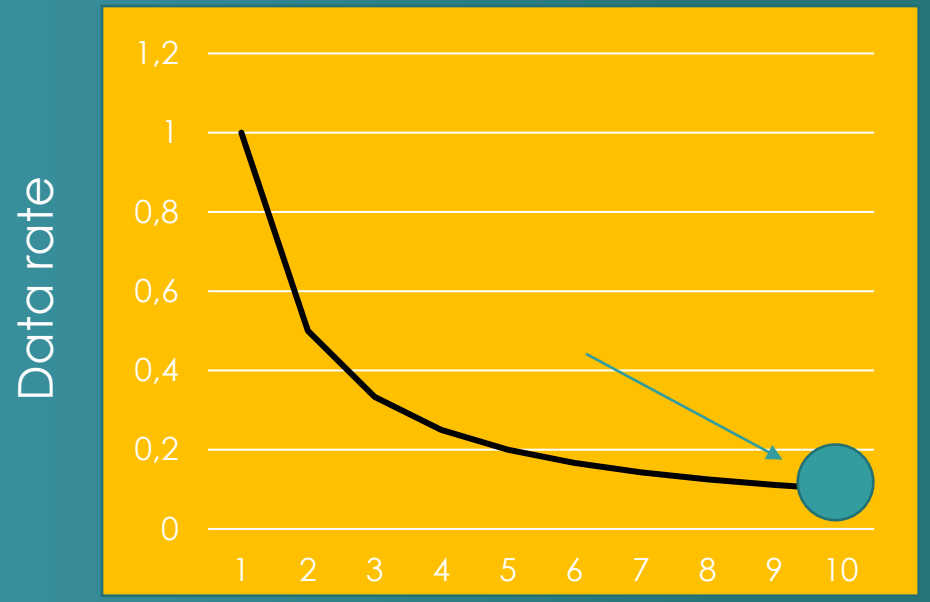
T_o = Absolute temperature of the receiver input (Kelvin) = 290K

B = Receiver Bandwidth (Hz)

G = Antenna/system gain

The compromise to get high sensitivity is to keep the data-rate low → Long transmission packet length

LPWANs has typically long Tx time = Transmission packet length,
and works best for low data-rate applications



Long transmission packet length and collisions

- When node count increases, then the risk of collisions increase. Particularly in Random Access networks
- If the transmission packet length is long, then the risk for collisions increases. A long pulse is vulnerable for interference longer than a short pulse. It is a parallel to likelihood of waiting at railway crossing for a long a freight train, vs waiting for a short passenger train

- To reduce the transmission packet length and the risk, then the packet size should be kept small, and the data-rate should be as high as possible (but keep in mind that high data-rate reduce the range, so it is a compromise)

Update rate and node count

The packet transmission rate is how often does the system send a packet to or from the gateway. The higher the packet transmission rate, the lower is the maximum node count

This is like a traffic jam, the more cars, the higher is the likelihood of a collision. It is the same with the RF packets

How to reduce increase the packet transmission rate

1) Reduce the packet transmission rate by local data pre-processing. Store data and send it only the data needed, when it is needed. Think about sending changes, rather than raw data for example

Media Access Backgrounder

Four schemes for Media Access in LPWANs

1) Random Access (fire and forget)
A device will send out a packet regardless of environment, and assume that the packet is sufficiently received

2) Pure ALOHA, Random access with Ack/Retry
A device will send out a packet regardless of environment, and wait for acknowledgement, and send again if needed

3) Aloha with LBT,
A device will check if a channel is free before sending and if the channel is occupies wait a random time before retry.

4) Time synchronized / Channel synchronized, TSCH
The system controls the time when a device can send in time and in which frequency.

Random Access

"Fire-and-forget"

A node will send at a random time and does not get any feedback if the transmission is successful

Positives:

a) The low power consumed at the network node, during the time between transmissions
b) A low data-rate is not a problem, if the node count is not too high
c) Simplest modem, a node does not need a receiver

Concerns:

a) Packet loss is fairly high when the node count increases. Some packet loss can be countered by sending redundant data.

Good for applications where some packet loss is not a big problem and the transmission rate is low

Pure Aloha

Wait for acknowledgement

A node will send at a random time and will get an acknowledgement (ack) . The node will resend if no ack

Positives:

a) The packet loss is reduced vs Random Access

b) Fairly simple modem implementation

Concerns:

a) No alternative is open other than a retry

b) Requires short packets to support ack/retry. Short packets requires high data rate → lower range

Good for applications where the low packet loss is important, and the longest range is not needed

Aloha with LBT

A device will check if a channel is free before sending and if the channel is occupies wait a random time before retry.

Positives:

a) The packet loss is further reduced

b) Handles noise environment well

Concerns:

a) Fairly complex modem

a) Requires short packets to support ack/retry. Short packets requires high data rate → lower range

Good for applications in noisy or congested environment where the low packet loss is important, and the longest range is not needed

Time synchronized / Channel synchronized, TSCH

The system has a common time and channel schedule where each node when to send and at which channel

Positives:

a) The packet loss is further reduced

b) Handles noise environment well

Concerns:

a) Very complex modem

b) Some bandwidth is used to keep synchronization alive

c) High power consumption, as the nodes cannot go to deep sleep

Good for applications in noisy or congested environment where the low packet loss is important, and the longest range is not needed and power consumption is not a big concern

Duty cycle and European regulations

- There are two parameters that decide the duty cycle of a device; Transmission packet length and the packet transmission rate
- This is particularly critical for a star network with downlink communication and high node-count, as one gateway will talk to all the nodes.
- There are work arounds, but a high node count network needs to take this into account

  Ways to ease the problem includes:
  - Short transmission packet length
  - Low packet transmission rate
  - No, or very limited downlink transmissions

Frequency	Output Power	Duty Cycle	Percent of the band
863,0 -868,0	25mW, 14dBm	0,1% or LBT + AFA	71,5%
868,0-868,6	25mW, 14dBm	1% or LBT + AFA	8,5%
868,6-869,7	10mW, 10dBm	1%	1,5%
868,7-869,2	25mW, 14dBm	0,1% or LBT + AFA	7%
869,2-869,3	10mW, 10dBm	0,1%	1,5%
869,3-869,4	10mW, 10dBm	1%	1,5%
869,4-869,65	500mW, 27dBm	10% or LBT + AFA	4%
869,65-869,7	25mW, 14dBm	10%	0,5%
869,7-870,0	25mW, 14dBm	1% or LBT + AFA	4%

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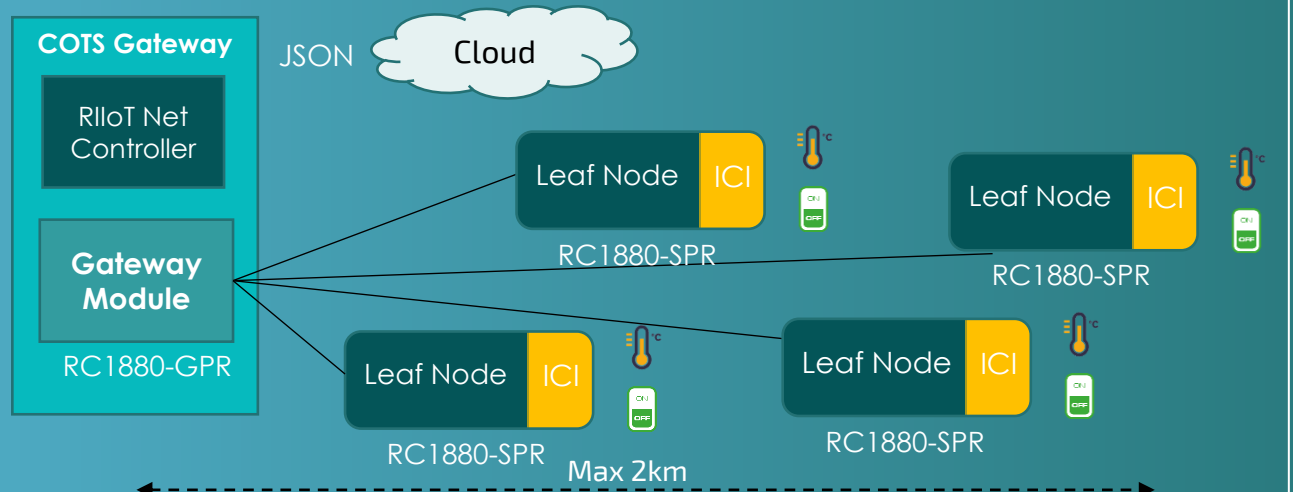
Embedded Wireless Solutions

Fast to Market.
Proven Quality.

RIIoT™ by Radiocrafts,

An IIoT Wireless, long range, 2 way symmetric, network in a module - Developed for you to easily create your own industrial grade access network with cloud connectivity



- Long range, up to 2 km urban
- Very low power
- Very high node count
- 2-way symmetric
- Connects:
  - any sensors
  - any controllers
- No license fee
- No subscription
- 5 or 50 kbps data-rate
- Pre-certified

The SPR and GPR Modules are the core of the network nodes and incudes the complete RIIoT network, together with an Linux application in the gateway

The remaining customer development time for a complete Industrial IIoT network is a few weeks.

A Gateway Dongle is available from Radiocrafts for simple certification

Development by the customer:
- Sensor/Controller chips and interfaces
- Sensor/Controller data formatting & data processing
- PCB and power
- Enclosure

RIIoT™ by Radiocrafts

Supporting very high node count

RIIoT support very high node count, which is a problem in many LPWAN networks, where long range has been the main focus

RIIoT has still long range, but not the longest, as the features that support high node count will not support longest range.

The problem with high node count comes primary from packet collisions, so the challenge is to avoid and recover.

Avoid packet collision is supported in RIIoT by:

- Short transmission packet length → RIIoT is down to 4.5ms in the 50kbps mode
- Reduce the amount of transmitted data → RIIoT supports data pre-processing in the ICI framework
- Listen Before Talk → No transmission when the channel is busy
- Frequency Hopping → Use the least noisy channels for transmission

Recover lost packets is supported in RIIoT by:

- Acknowledge / Retry on MAC level → RIIoT will automatically resend packets that are not confirmed received.

RIIoT™ by Radiocrafts

In summary

Long Range Wireless networks can support very high node counts over a thousand nodes, but you cannot support the longest range and the highest node count at the same time

Pay attention to:

1. Radio performance (selectivity)
2. Transmission packet length
3. Packet transmission rate
4. MAC, Media Access Control
5. Regulatory requirements

Design you system smart by:

1. Reduce the amount of transmitted data, by intelligent data pre-processing
2. Reduce the packet transmission rate, to only send when needed
3. Consider application layer intelligence, to recover lost data

Consider RIIoT if you high node count

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Q&A

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