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Life After LORAN – A Future For Terrestrial Radio

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The Question…

With pressures on cost, power & size, particularly for small cells, do we need something more?

We were asked: "Is it possible to re-use wireless technology to lower cost, size & power?"

Different backhaul technologies are coming fast and furious, is synchronization keeping up?

Are the available synchronization technologies capable of covering upcoming sync requirements?

Let's start with what we (all?) agree on…

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❑ **Time or Phase alignment is required in network equipment**

- Some more than others
- Some sooner than others

❑ **Time or Phase provision choices include…**

▪ GNSS	(GPS, GLONASS, Galileo, IRNASS, BeiDou, QZSS)
▪ PTP	(IEEE1588, Precision Time Protocol)
▪ NTP	(Network Time Protocol)
▪ OTA	(Over the Air techniques)
▪ eLORAN	(Long Range Navigation)
▪ Cs	(Caesium or other highly stable clock)

Which options satisfy availability, accuracy & cost criteria?

Existing (?) Time & Phase Delivery Options

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Time delivery option	Use today	Robust Availability	Robust Accuracy	Cost	Notes
GNSS	Extremely widespread	👎	👍	👎 *antenna	Easily blocked High OPEX
PTP	Growing rapidly	👍	👎	👍	Network engineering can fix accuracy
NTP	Widespread non telecom	👍	👎	👍	V4 req'd for accuracy Only V3 widespread
OTA	Not widespread	👎	👍	👍	Needs standard Requires air i/f
Cs or other	The 'root' of all clocks today	👍	👍	👎	Expensive Needs to be aligned

High Quality phase delivery costs

Time  **&**  **Money**

Telecom is widely settling on the following selection

GNSS & PTP assisted by SyncE

GNSS for accuracy

Primary: Where & when available, use GNSS

Backup: SyncE &/or PTP

PTP for availability

Primary: PTP is available everywhere even when no access to GNSS

Backup: SyncE

Is PTP our only choice?

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We have chosen PTP assisted with SyncE when GNSS is not feasible

- However, we know that SyncE support is not always possible
- How about when the network is hostile to PTP & network engineering is not an option

The Needs:

Accuracy of GPS with ‘deploy-ability’ of PTP

Would like:

Lowest cost, lowest power, smallest size

If we experiment with an existing wireless technology could it help?

IoT national networks using “LoRa”
LoRa = Long Range

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- **Operators are deploying Long Range national networks for IoT**
  - Applications such as asset tracking, smart grid and many others driving IoT
  - Coverage in-buildings is possible with links more robust than GSM
  - Based on Semtech’s LoRa silicon devices

- **Extremely low power**
  - 10 year battery life

- **Co-exist with LTE, WCDMA & GSM etc.**
  - Gateways are sharing cell towers

This technology includes ranging and location of end-points

As with GNSS, when you have position, you have time.

LoRa IoT Radio specifications

- **Frequency bands:**
  - 868MHz, 915MHz, 2.4GHz (significantly lower range)
- **Tx Power levels:**
  - up to 14dBm (slight differences in regions)
- **Power consumption:**
  - Endpoint Transceiver:
    <100mW when active at 14dBm TX power
    <1uW when standby
- **Link Budget:**
  - 168dB- Exceeds GSM cell link budget by 10-20dB
- **Modulation:**
  - Spread-spectrum

Let's start by checking 3 parameters:

Before we look at the delivery of Phase synchronization, lets look at 3 important parameters of the base wireless technology…

1. **Can we get good urban coverage and in-building penetration?**

2. **Is it robust to interference and aggressive blocking?**

3. **Is coverage predictable?**

Then let's ask…

Is the IoT technology good enough to distribute phase synchronization?

1: Does it have good urban coverage? NYC Field Test: 868MHz

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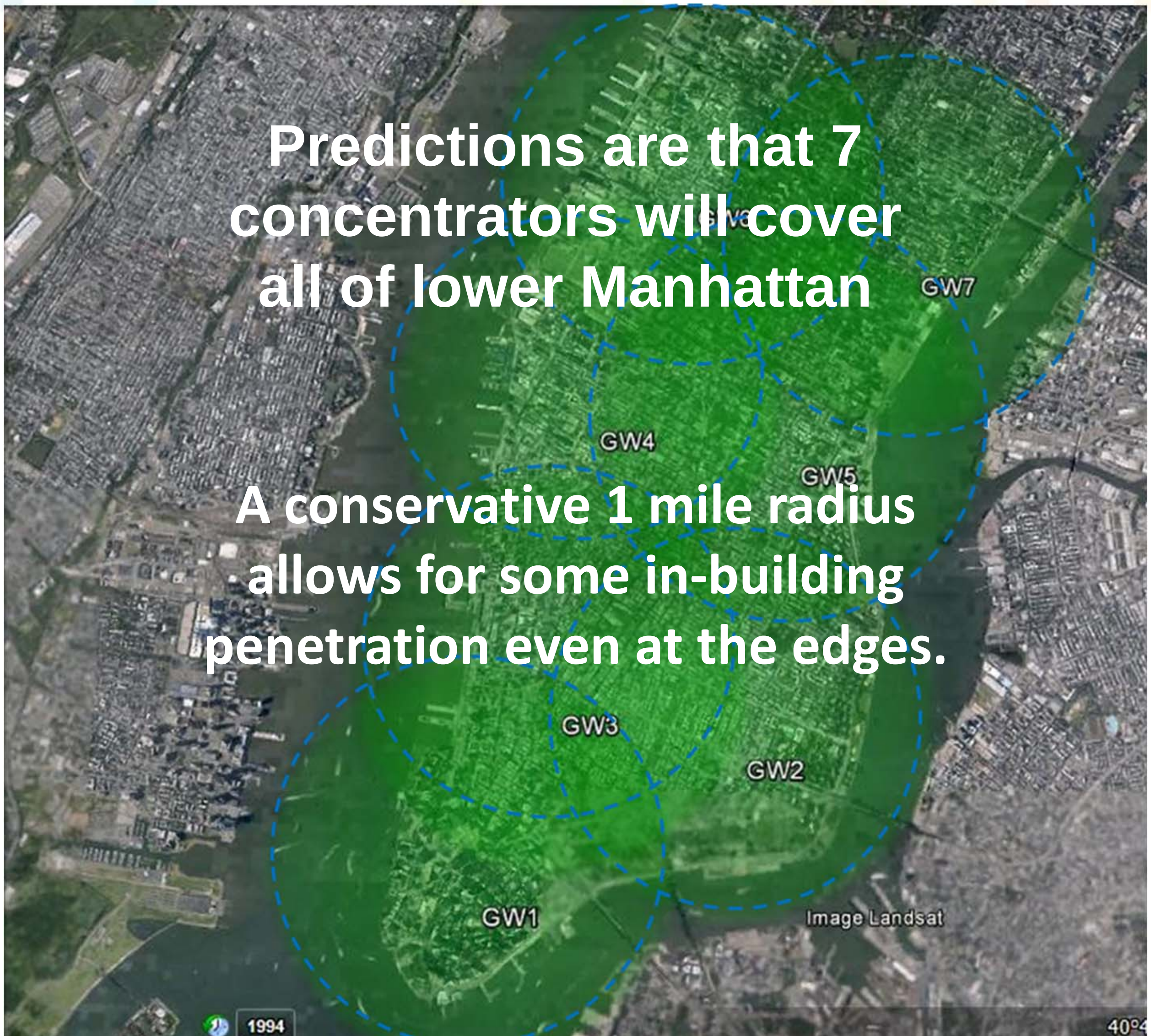

1: Does it have good urban coverage?
Outside test: Walk Straight North to the Met

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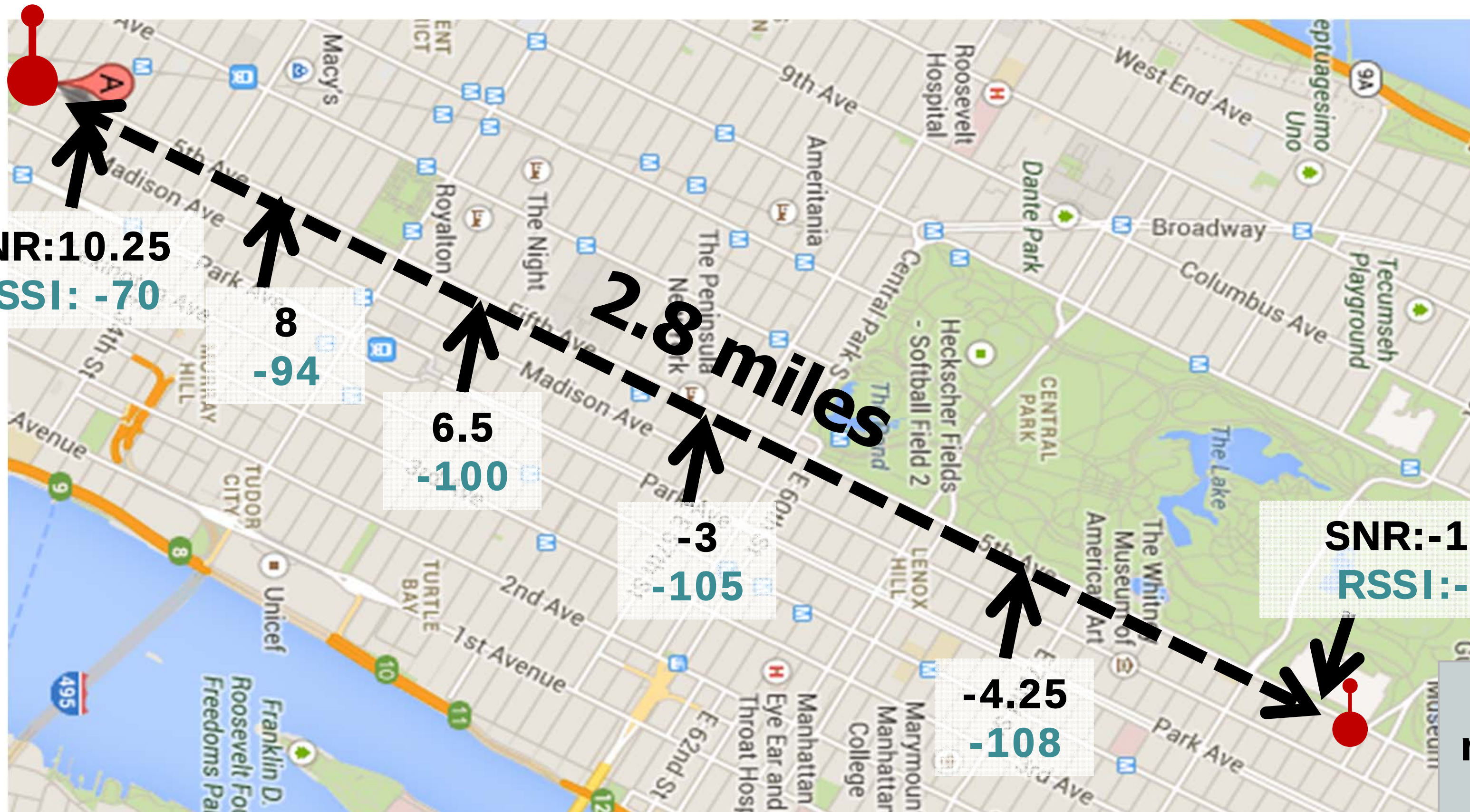
LORA concentrator on roof top



LoRa node on street

SNR and RSSI were measured on valid packets received by roof-top concentrator
With max spreading factor LoRa operates down to SNR of -20dB (868MHz)

1: Does it have good urban coverage?
Extreme Urban: Subways and In-buildings

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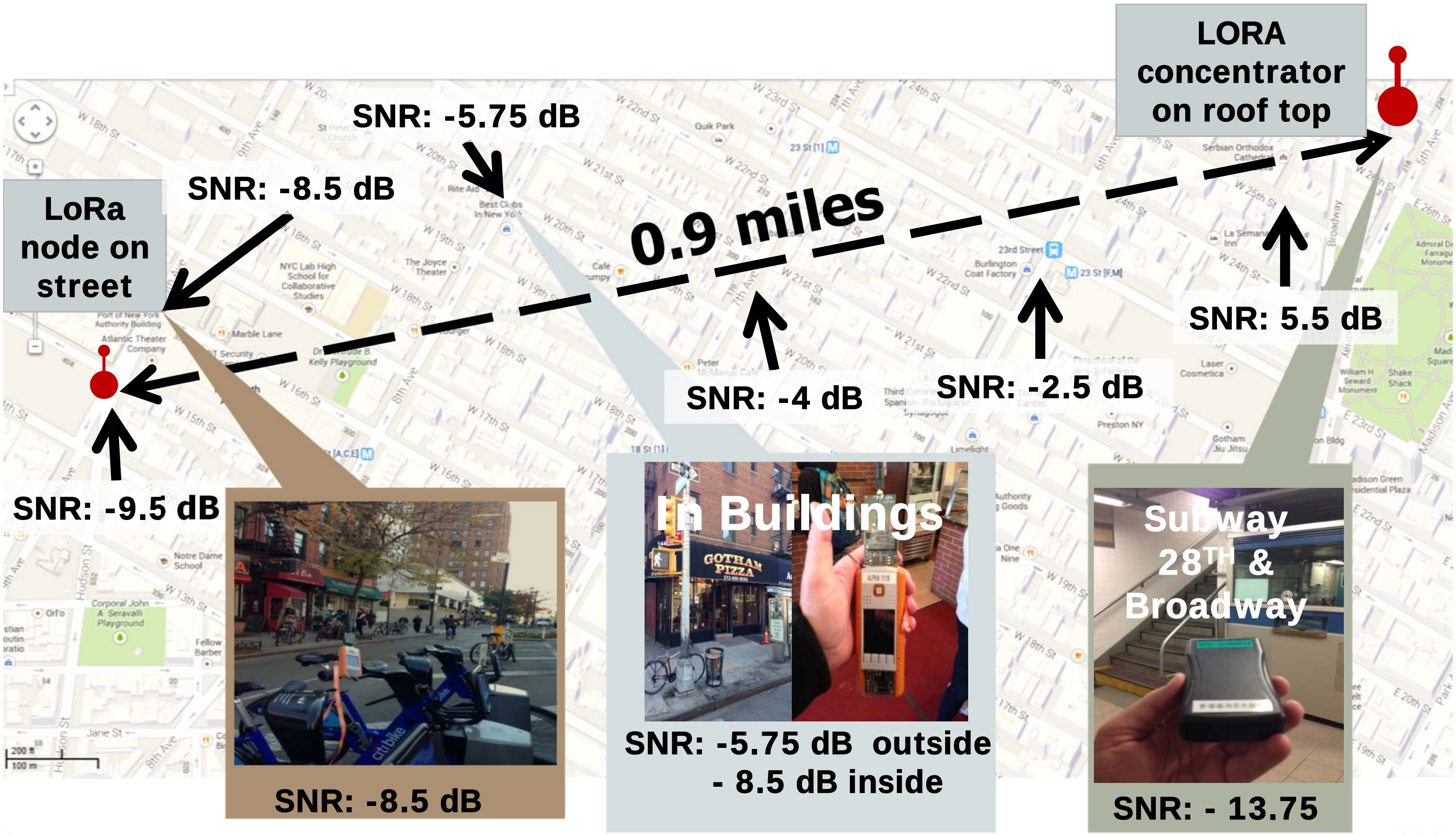
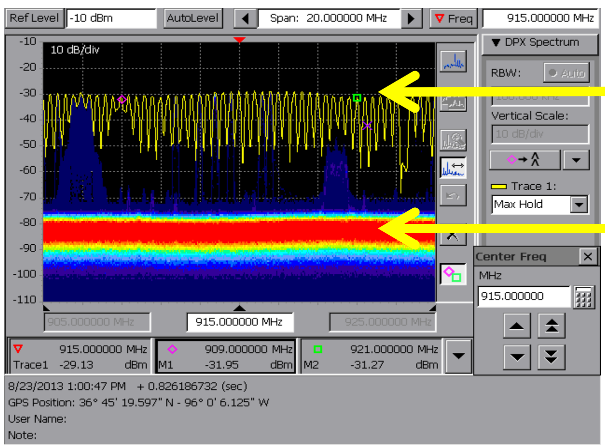


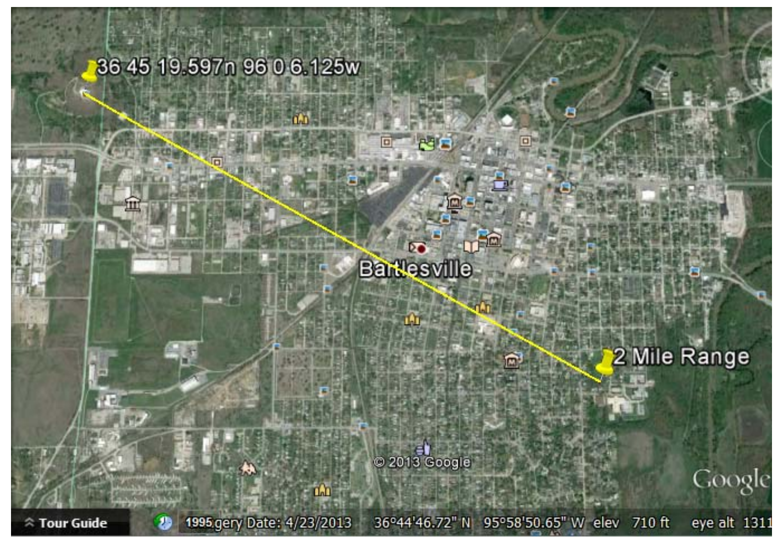
2: Is it robust against interference?
Field Test- Bartlesville Oklahoma- 868MHz

Target:
Reach 2 miles to water pit in the presence of extreme interferes



-30 dBm interferers

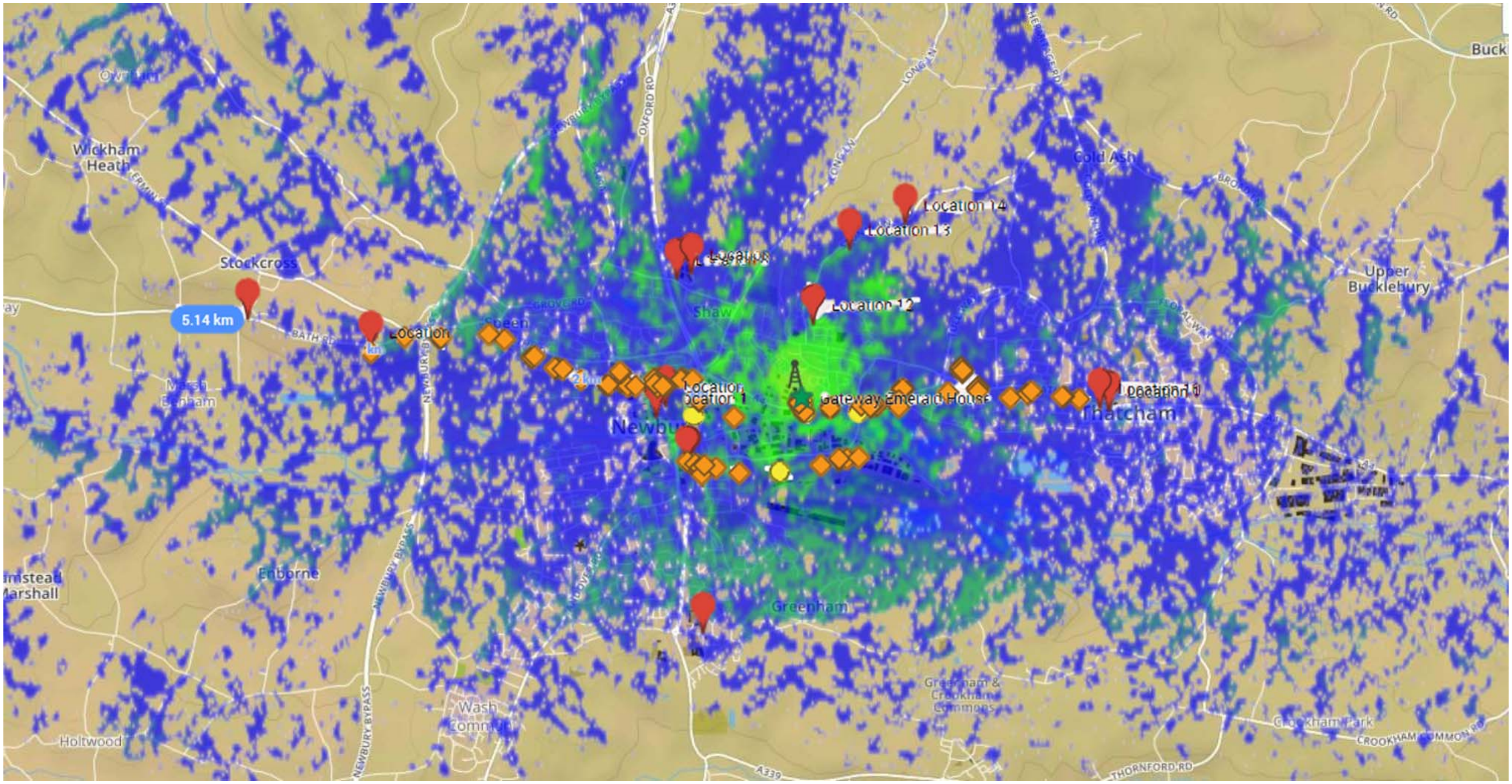
-80 dBm Ambient Noise Floor



Theory tells us that this technology has some of the highest known immunity to interference- in practice it seems to work

3: Is it predictable?
Do measurements align with predictions?

Theoretical model of single gateway in Newbury, UK. And the measured results…



The 3 parameters are looking good:

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1. **Can we get good urban coverage and in-building penetration?**
   - Link budget significantly greater than GSM

2. **Is it robust to interference and aggressive blocking?**
   - Extremely robust to interference

3. **Is coverage predictable?**
   - Better than 95% alignment between predicted and measured results

IoT technology looks like a good candidate to transport synchronization

Two Approaches to LoRaSync

❑ Two-way message flow

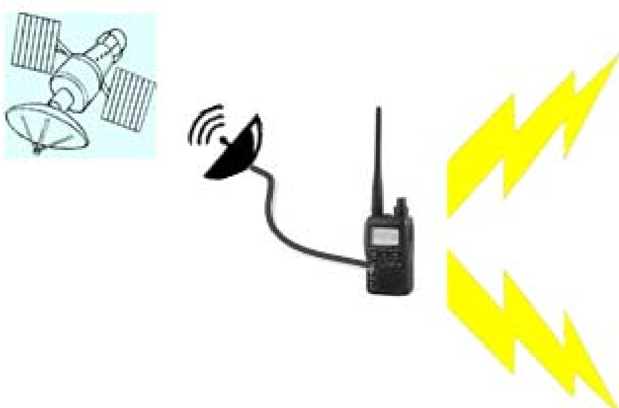
- Similar concept to PTP
- Master sends time to slaves
- Per-slave ranging mechanism measurements master to slave delay

❑ Triangulation

- Terrestrial GPS
- Gateways broadcast location and time information
- Nodes use this to calculate position and time

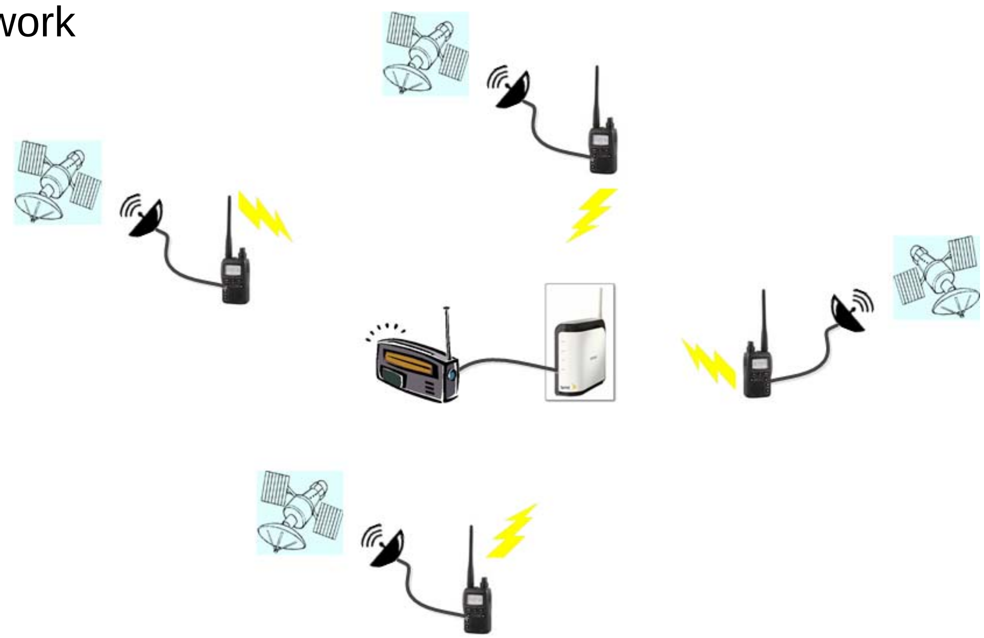
Two-way Message Flow

- Point-to-point or point-to-multipoint
- Peer-to-peer architecture
  - Same equipment at both ends
- Ideal for private local networks
  - In-building small-cell – P2MP
  - Sync across microwave link – P2P

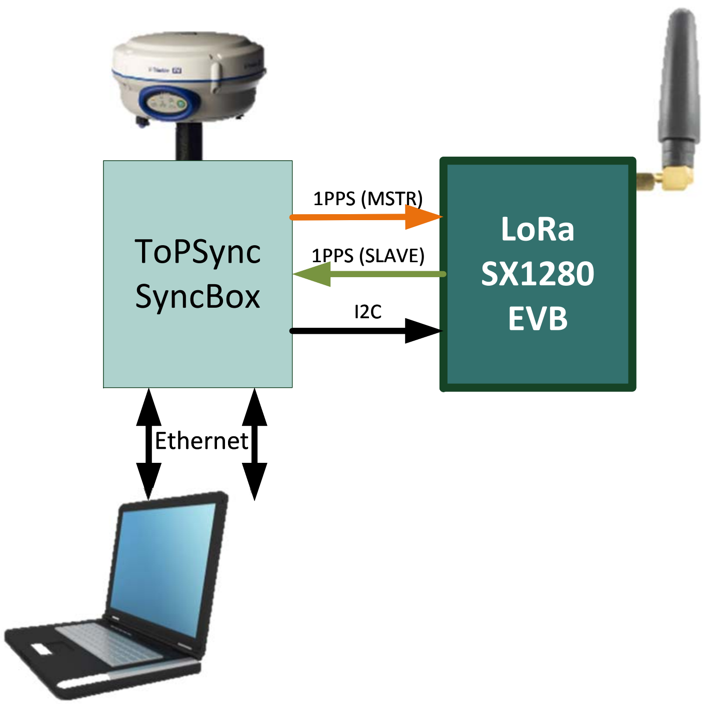


Triangulation

- **Gateways need no knowledge of nodes**
  - Unlimited fanout
  - But how do operators make money?
- **Needs sight of multiple gatways**
  - Can mitigate this with known node position
- **Ideal for wider-area public-networks**
  - Co exist with LoRa data network



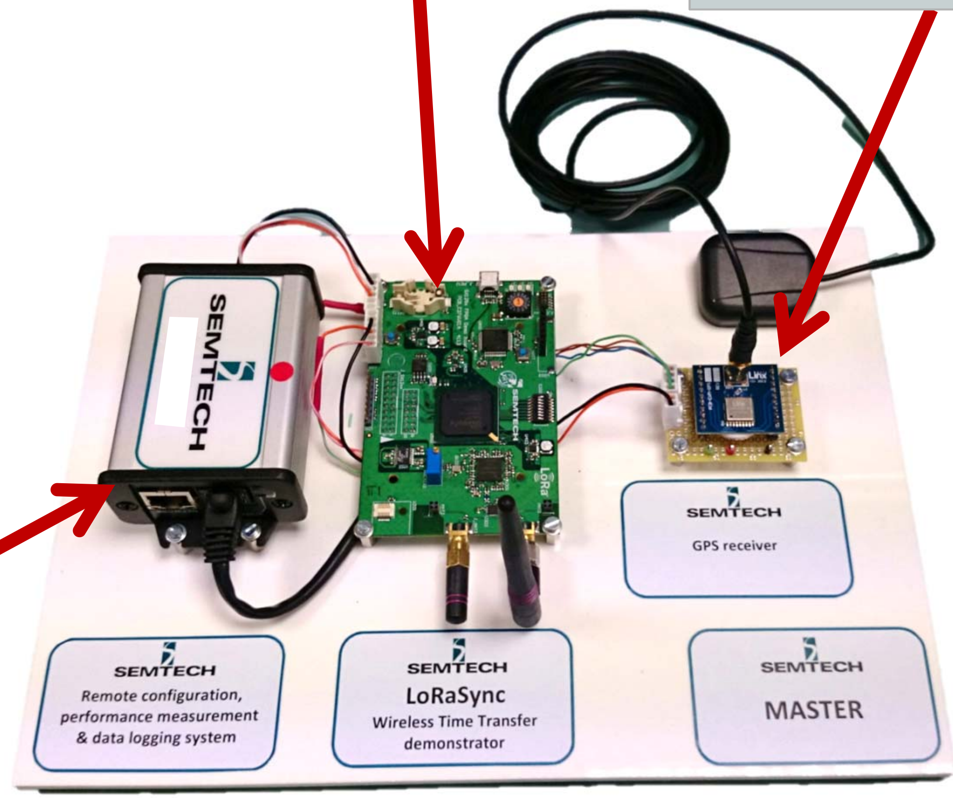
LoRaSync Trial and Demo system: The 'wireless time transport system'



LoRa Transceiver

GPS Receiver- provided to Master, & compared to Slave

ToPSync management, performance monitoring and PTP system



LoRaSync Channel Operation

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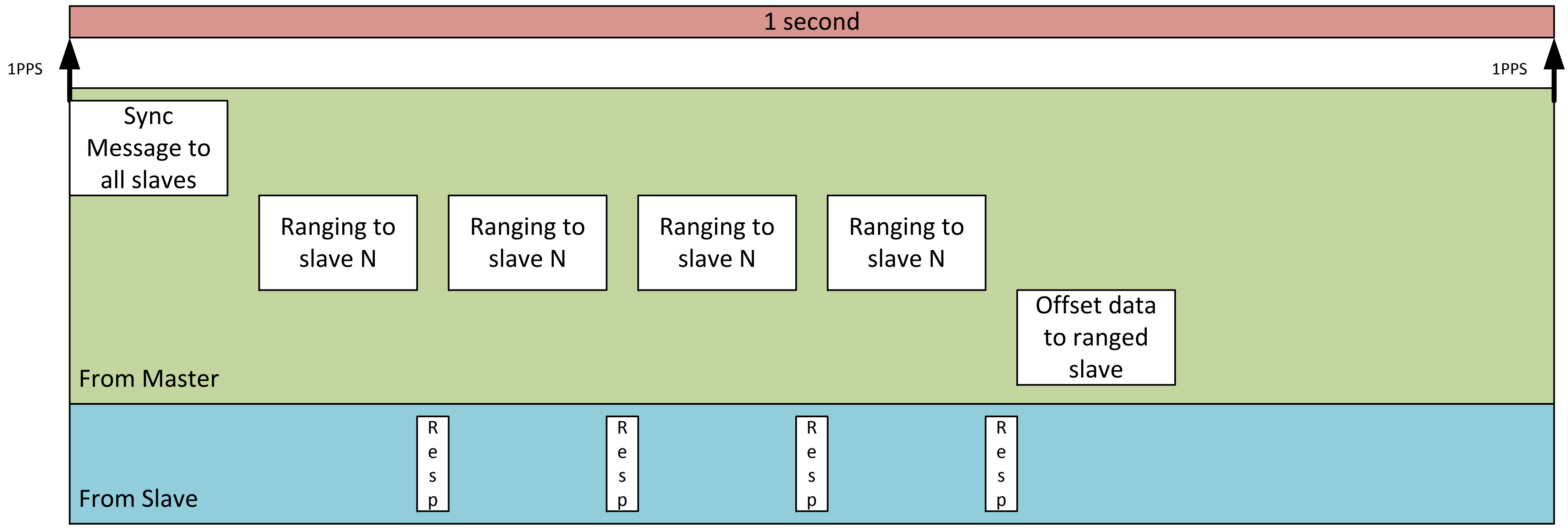

- **Each second a 'sync pulse' is transmitted to every slave**
- **LoRa slave generates 1PPS locked to the sync message**
- **Each second one slave is selected and multiple ranging requests are made**
- **Following the ranging, the calculated offset is sent to the selected slave**
- **ToPSync locks to the 1PPS from LoRa slave with the offset read from the slave**

First test of time transport: San Diego In-building, Line of sight Test

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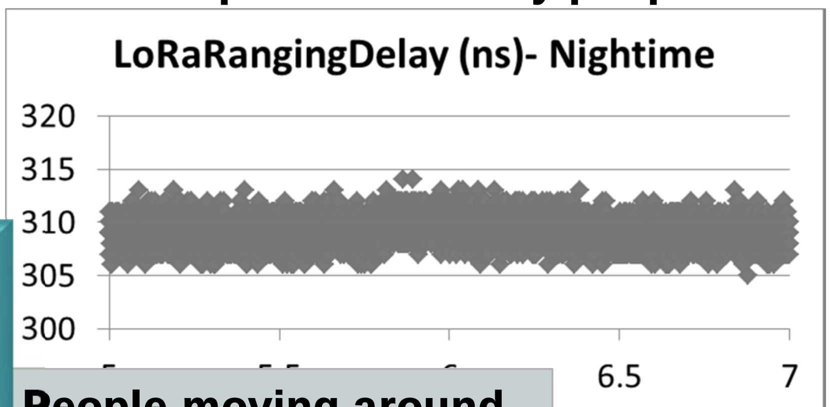
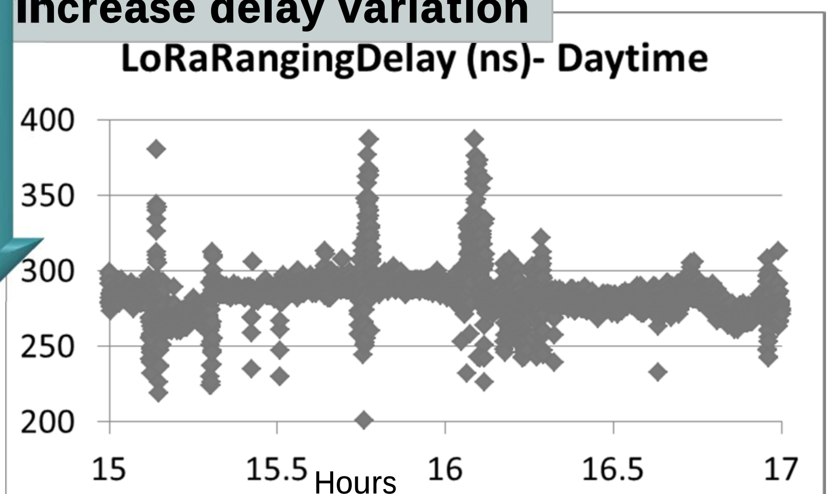
Short range 2.4GHz, 10dBm Tx power in-building test.
Straight path across one floor in building with strong direct path.
Horizontal path with many people walking in signal path.

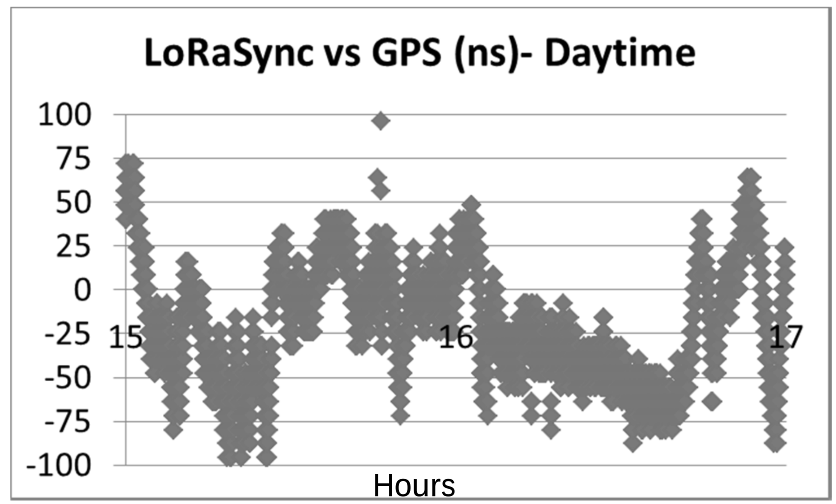


20 X increase

People moving around- increase delay variation



Unfiltered LoRaSync vs GPS
Daytime: + / - 50 to 100ns



San Diego In-building, Line of sight Test

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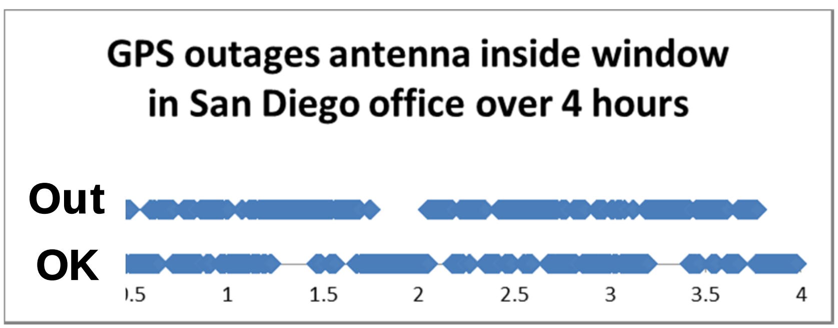
Observation 1: Line-of sight performance is good; unfiltered results are OK

Observation 2: Solar window film wreaks havoc on GPS & GLONASS

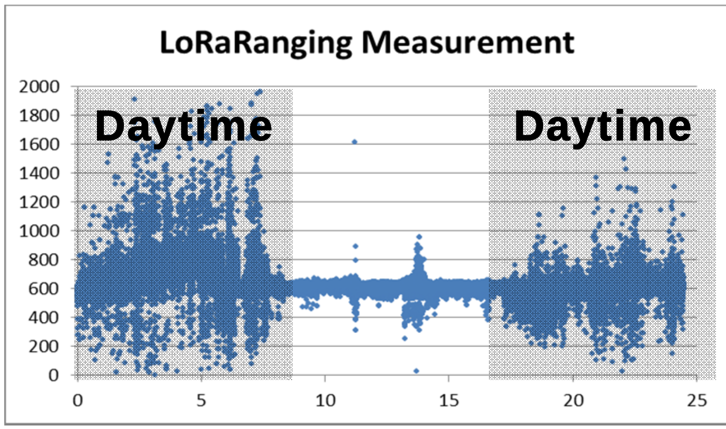


Antenna placed outside window had only one 5 second outage in 18 hours

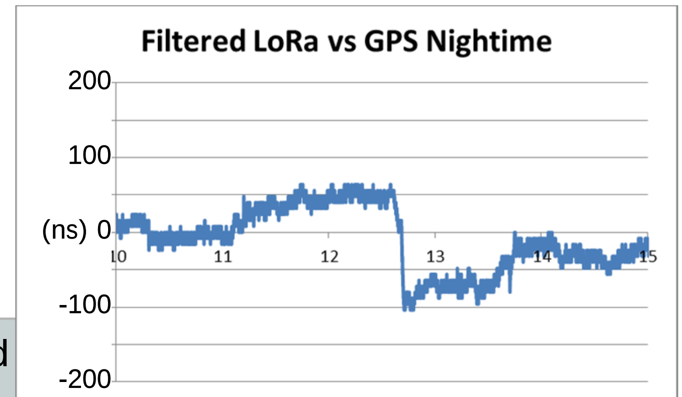
Antenna placed right inside window had around 50% outage

Romsey, UK In-building test

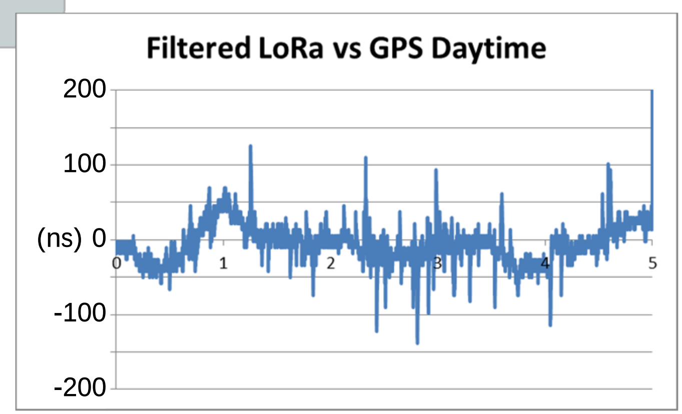
Short range 2.4GHz, 10dBm in-building test.
Set up path diagonally across building with no direct path (only multipath).
Production test suite and laboratory within direct path.



Ranging results vary much more with movement of people and objects



50mHz filtered results are acceptable



Romsey, UK In-building test

Observation 1: **Multipath creates a lot of noise on the ranging mechanism but a simple filter with a 50mHz pass-band gives good results.**

Observation 2: **People and general activity increases multipaths and delay variation a lot. It is significantly quieter at night.**
Multi-path algorithms can significantly reduce this effect. So far no algorithms have been tested.

Summary

- It is feasible to use low power wireless technology to transport time
- Nationwide IoT network could sync small cells and many others
- Power, size and cost savings would likely be significant