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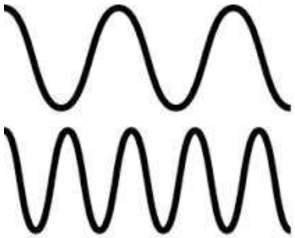
Holdover – Who needs it?

ITSF 2014

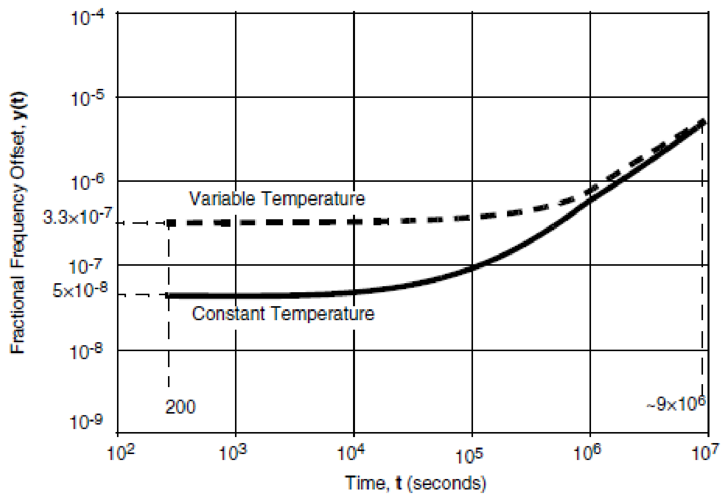
What is holdover?

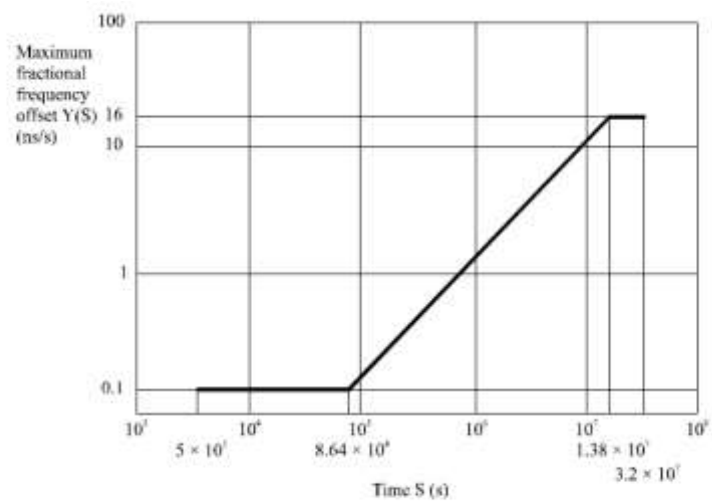
- **Normal sync operation**
  - Device locks to a clock from an external source
    - In-band with data (T1/E1, SONET, SyncE)
    - Separate source (GPS)
  - Can also pass clock downstream
    - After necessary filtering
- **But what if something goes wrong**
  - No external clock sources available
  - We're on our own
  - Only option is keep doing the best we can …
  - … for as long as we can
  - Might be able to operate with reduced performance
- **Principle of holdover**
  - Acquire data about the reference while locked to it
  - Use that data in conjunction with local oscillator to maintain output
  - Holdover quality depends on local oscillator stability and "holdover data"

Frequency Holdover



- **Traditionally applications only required frequency**
  - Holdover meant maintaining frequency error below a certain level
  - Typically specified directly or by an MTIE mask





- **These limits are fairly lenient**
  - 24 or 72 hour frequency holdover really isn't a problem

Time Holdover

- **Now, time is needed everywhere**
  - Cellular backhaul is a big driver
    - TDD
    - CoMP
    - eICIC
- **Benchmark phase error target is 1 µs**
- **That's not much …**
  - Remember that time is the integral of frequency error
  - Errors add up very quickly
- **1.5 µs over 24 hours:**
  - Fractional frequency error = $1.5*10^{-6}$ / (24 * 60 * 60)
  - = 17.4 ppt
    - That's part per trillion – not million .. not billion … *trillion*
- **Time holdover puts massive requirements on local oscillator**

Oscillator Options

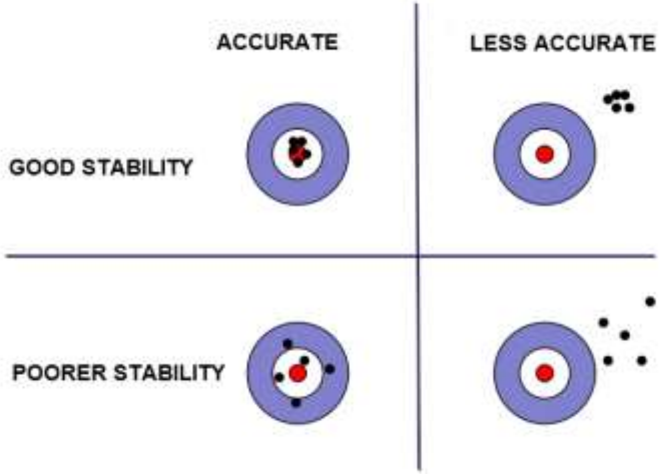
- **Factors determining holdover performance:**
  1) Oscillator selection,
  2) Oscillator selection
  3) And … Oscillator selection

- **There's only really two options …**
  - Quartz-based
    - TCXO
    - OCXO
    - TCOCXO
  - Atomic-based
    - Caesium beam
    - Rubidium
    - CSAC (Chip-scale atomic clock)

Accuracy vs Stability

❑ Important not to confuse terms

- Accuracy
  - How close to marked frequency the oscillator is initially
- Stability
  - How the frequency changes over a period of time



❑ Holdover only cares about stability

- Accuracy is compensated for by comparing frequency to reference while locked
- Stability over holdover period is key
  - No additional reference to compare to

Quartz Oscillator Options - TCXO

- **TCXO – Temperature Compensated Crystal Oscillator**
  - Simple AT-cut crystal
  - Operates at ambient temperature
  - Measures temperature and compensates for it
    - 3rd order or higher polynomial
    - Adjust frequency by varying load capacitance

- **Cost – Low ($5 +)**
- **Size – Can be tiny (5 x 3.2 mm or smaller)**
- **Power – Low (no heating element)**
- **Stability – Okay (0.1 – 1 ppm after 24 hours)**

Quartz Oscillator Options - OCXO

- **OCXO – Oven Controlled Crystal Oscillator**
  - Often an SC cut crystal
  - Uses heating element to maintain stable temperature
    - Above worst case ambient and optimised for SC crystal stability

- **Cost – Higher ($25 +)**

- **Size – Larger (often 1” x 1”)**

- **Power – Higher (Heating element)**

- **Stability – Good (1 – 10 ppb after 24 hours)**

- **TCOCXO is hybrid of TCXO and OCXO**
  - Temperature compensation and stabalization
  - Between TCXO and OCXO in all parameters

Atomic Oscillator Options

- ❑ Combines "physics cell" with crystal oscillator
- ❑ Tune RF excitation to match atomic transition of caesium or rubidium
- ❑ Quartz oscillator then locked to RF frequency

- ❑ Cost – Very high ($500 ++)
- ❑ Size – Rb / Cs beam – very large
  CSAC comparable to OCXO
- ❑ Power – Rb / Cs beam – high
  CSAC – low (can be battery operated)

- ❑ Stability – Good to excellent

Oscillator Summary

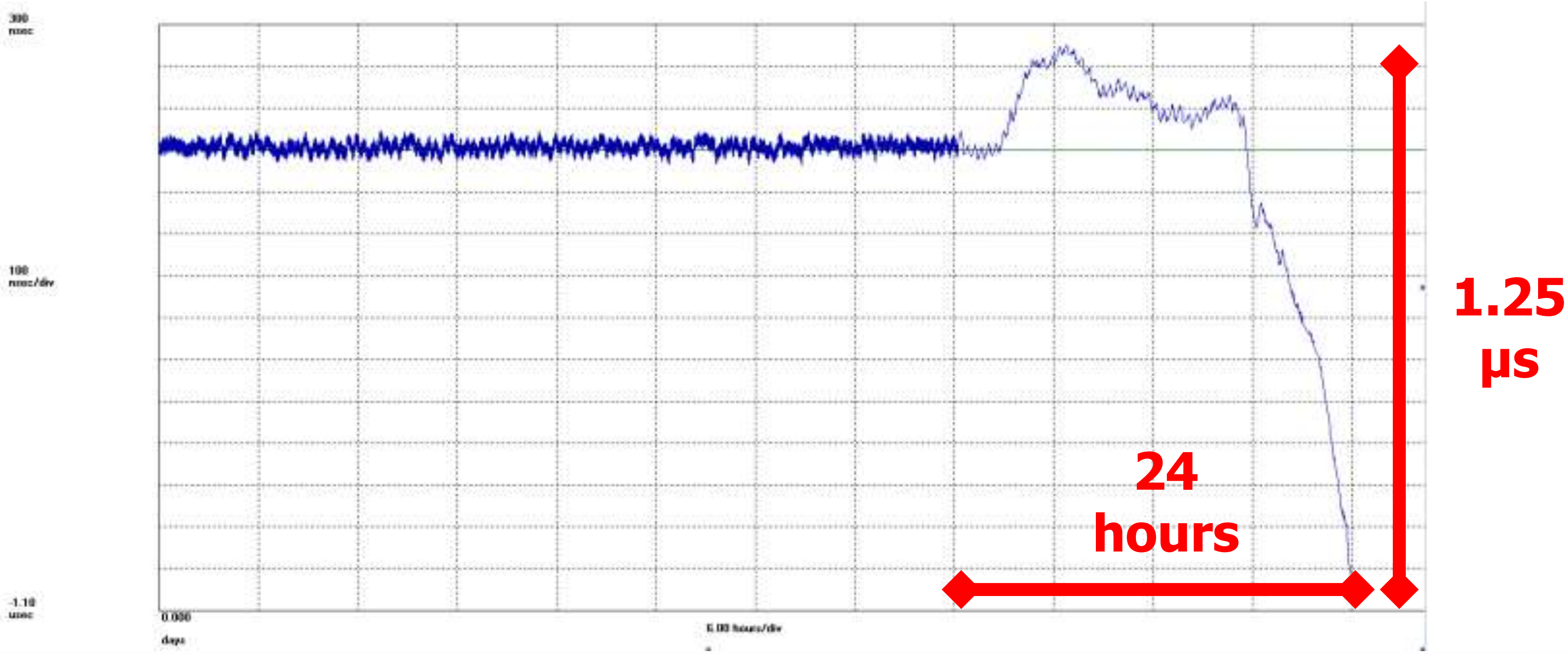
Technology	Oscillator Type	Stability	Cost	Size	Power
Quartz	TCXO				
	OCXO				
Atomic	Cs-beam / Rb				
	CSAC				

Compensating a Quartz Oscillator

- All holdover functions compensate for accuracy
- What about trying to compensate for stability too?
  - Affected by
    - Temperature
    - Voltage
    - Aging
    - Lessor factors such as output load
- Oscillator technology already handles temperature
  - Compensation (TCXO)
  - Stabilization (OCXO)
- Voltage and other factors should be stable in a good design
- Just leaves aging
  - Can we compensate for this?

Aging Compensation

- ❑ **Track oscillator frequency against reference while locked**
  - Just as for normal holdover
  - But now, try to determine second-order effects
- ❑ **It's not trivial … But it can be done**
  - Biggest issue is aging swamped by temperature

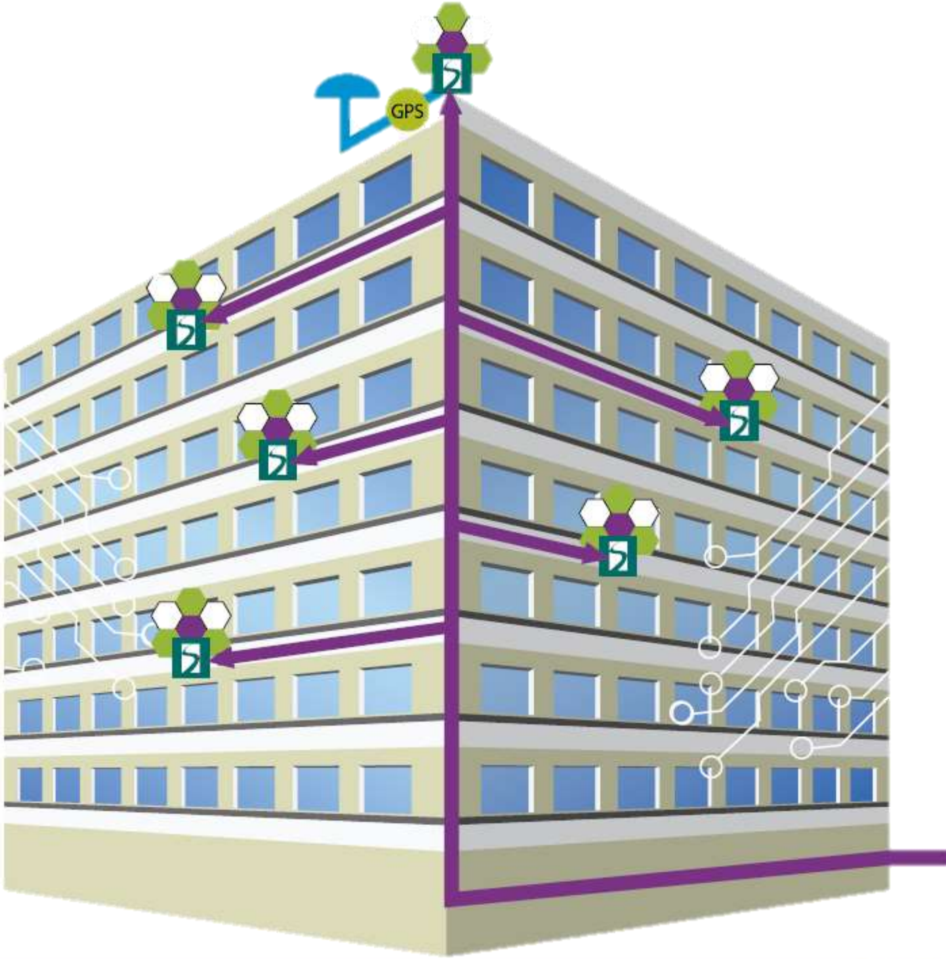


What Have we Learnt?

- **Time holdover is tough**
- **Atomic oscillators provide a good solution**
  - At a price
- **Quartz can provide a good solution**
  - Especially with aging compensation
  - But again, quality OCXOs are expensive
- **Perhaps the same everywhere doesn't work**
- **Can we get smart?**
  - Limit holdover to certain locations?
  - Limit holdover time?
  - Eliminate it altogether?

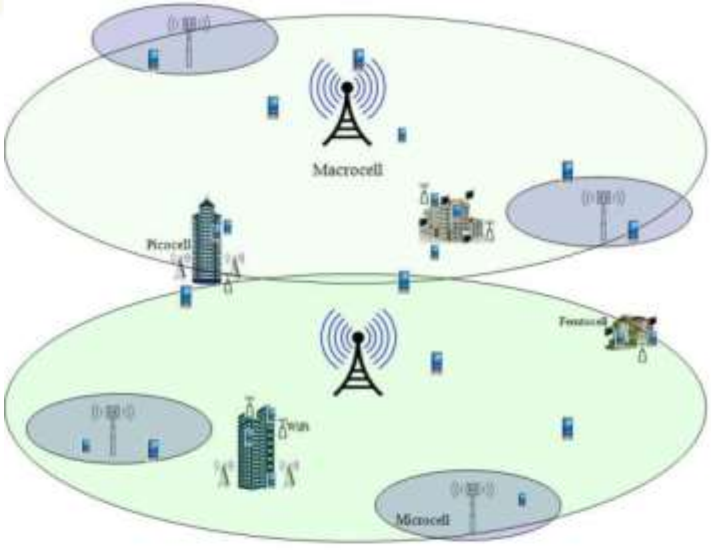
Where Do You Put Holdover?

- **Holdover is expensive**
  - Financial cost of oscillator
  - Potential for increased real estate
  - Potential for increased power
- **The better the holdover the more expensive it is**
  - Money, size and power
- **Cellular networks are moving to HetNet architectures**
  - Macrocells
  - Smallcells
- **Small cell aggregation point often associated with a macrocell**



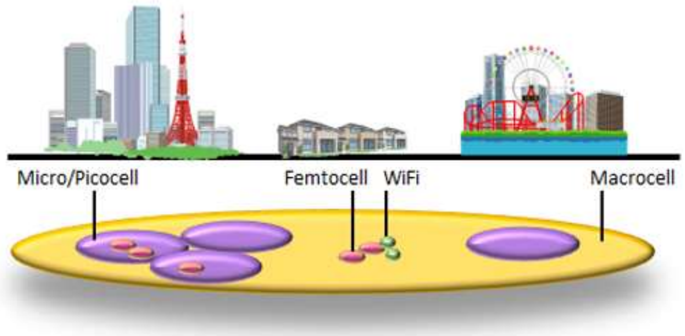
The Role of Small Cells

- Increased bandwidth
  - Especially good for high user density areas
- Improve in-building coverage
  - Energy efficient building are not good for RF
- Urban canyons
  - Fill-in for areas with poor macro coverage
- Temporary cell sites
  - Sporting events etc.



LTE Advanced Heterogeneous Network

- Typically a small cell has a single data link to the aggregator
  - Traffic + Sync
- Does a small cell need holdover?
  - If the link goes down data connectivity is lost
- Why not limit holdover to macrocells
  - And aggregators



Do we need 24 hours?

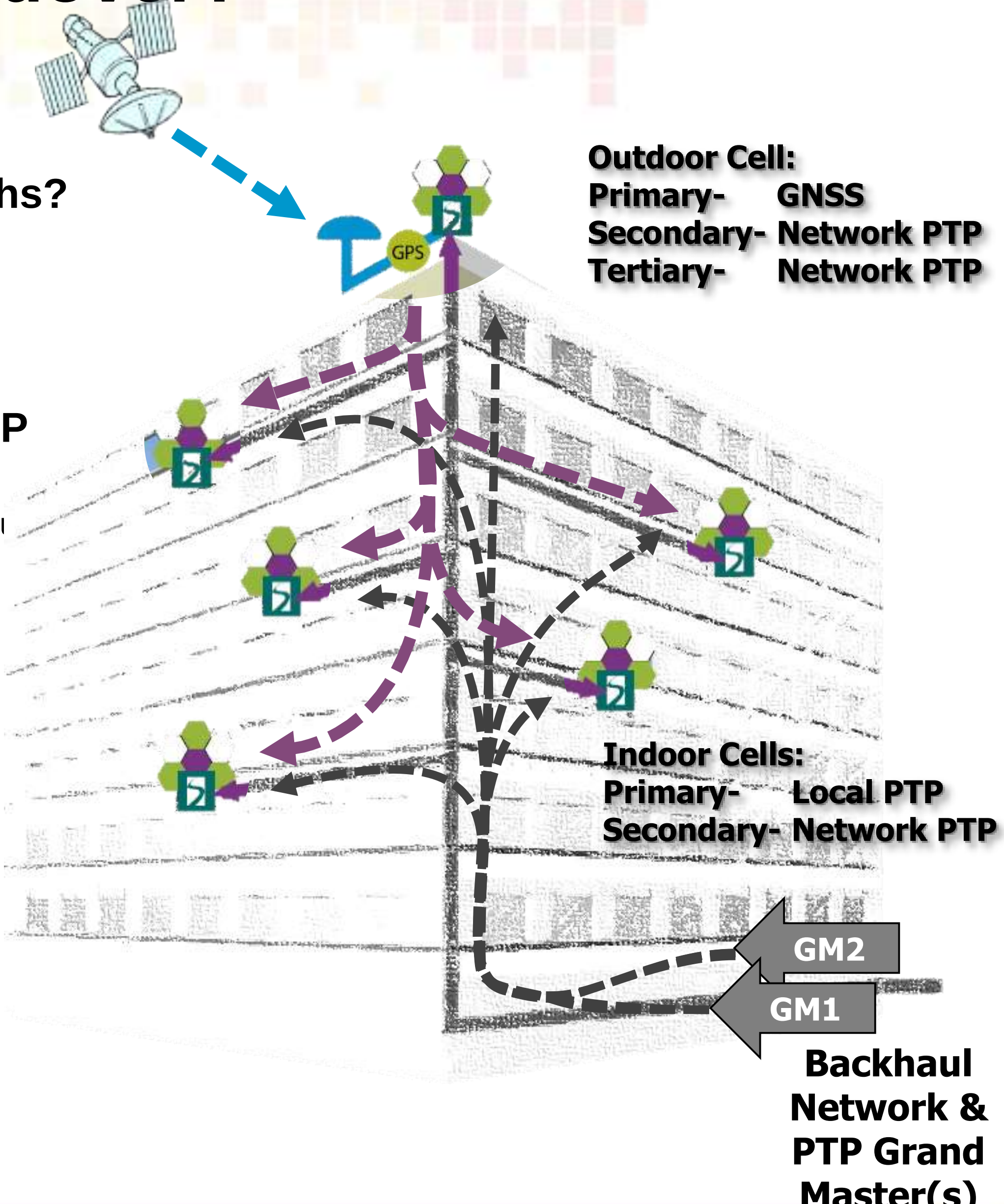
- One day is a long time
- How long does it really take to:
  - Identify a failure has occurred
  - Locate the failure
  - Roll a truck
  - Fix the problem
  - Return the equipment to operational state?

- Time will depend on equipment and location
  - Less for an in-building small-cell
  - More for a rural macrocell

- How about we get smart?
  - Provide minimal holdover function appropriate to equipment type
  - Dynamically manage network for longer outages
    - Reconfigure adjacent cells to work around outage

Do we Even Need Holdover?

- ❑ Why not just provide multiple sync paths?
- ❑ Automatically select GNSS if available
- ❑ Back up GNSS with Backhaul using PTP
  - Support 2x PTP Grand Master simultaneously
  - 3-way majority vote detects GNSS or PTP GM issu
- ❑ Embedded PTP Grand Master
  - **Distributes time to local indoor cells**
- ❑ Indoor Cells Prioritise Local Master
  - **Back up with a network G.M.**
  - **Indoor Cells automatically cancel asymmetry on failover to networked G.M.**

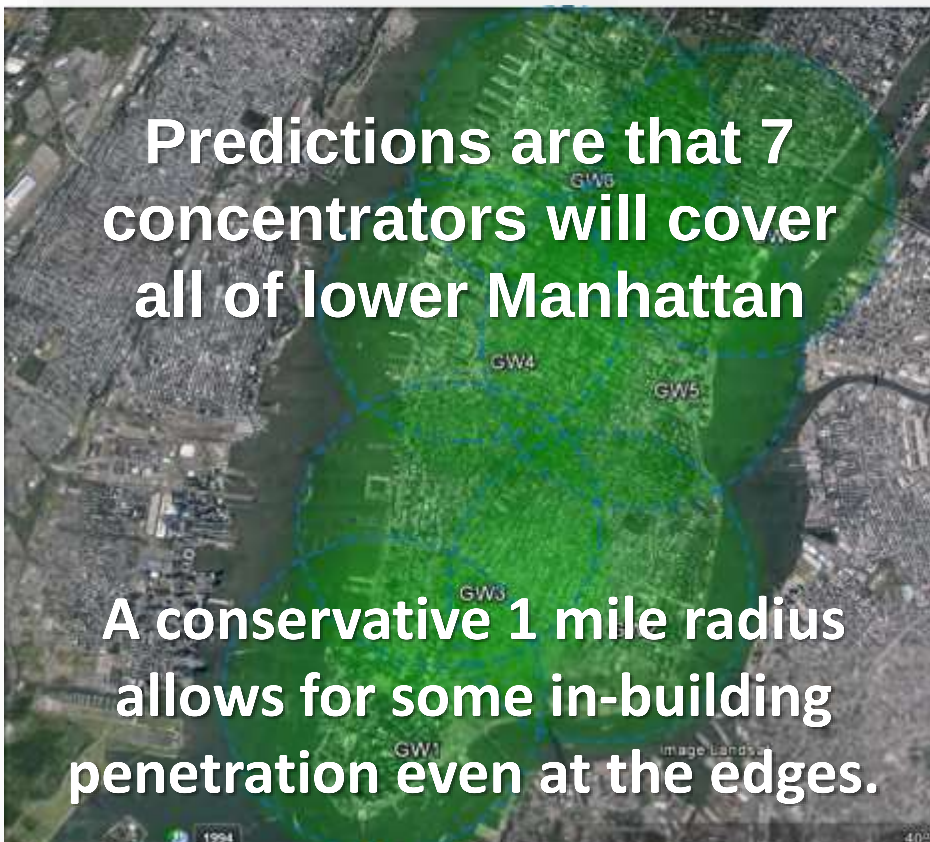


= primary PTP reference

= secondary PTP reference

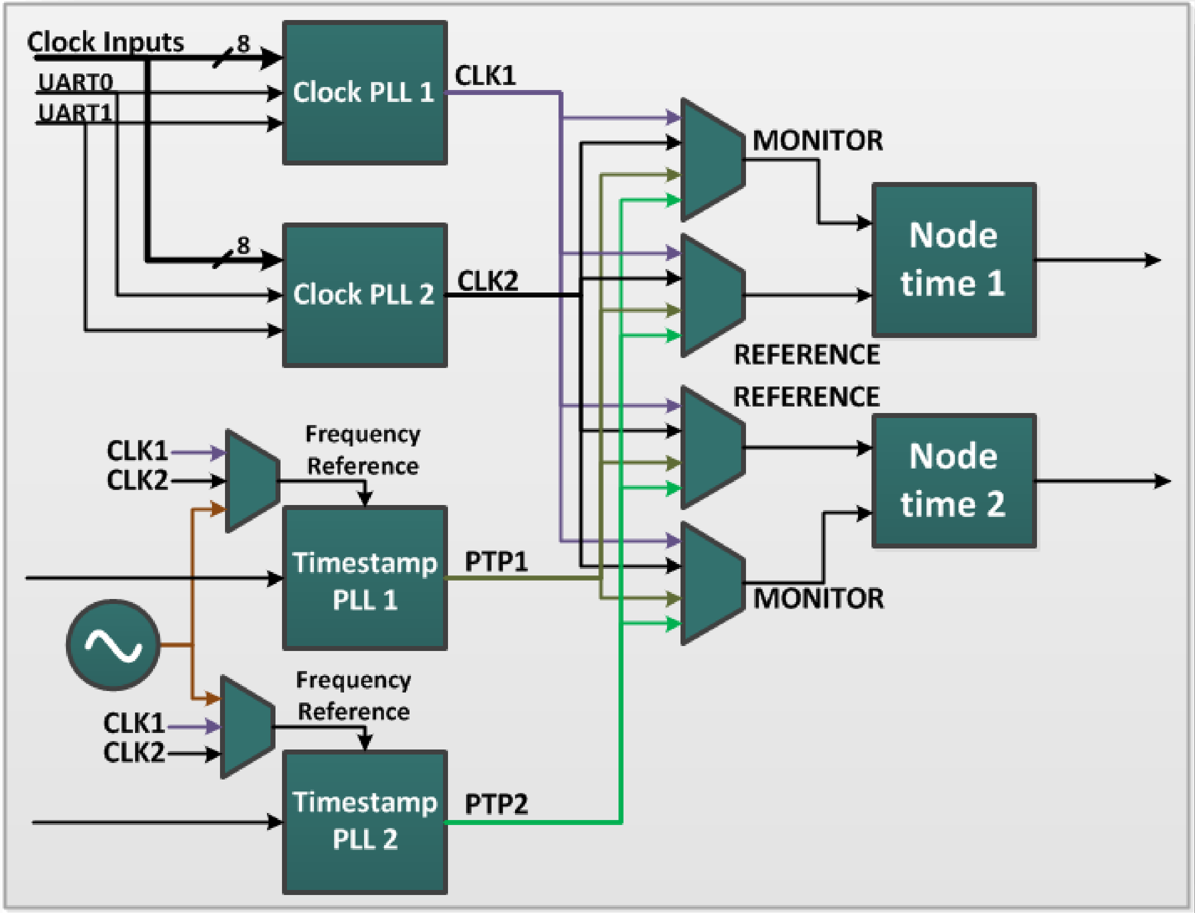
How About an Overlay Sync Network?

- **Build a local network to distribute sync using ISM radio**
  - Low cost
  - Ideal for urban areas



Making it Work

- ❑ **Multi-sync sources sound good in theory**
- ❑ **But need to be managed well to work correctly**
- ❑ **Can't have time jumps**
  - Need hitless switching
- ❑ **Equipment designs need to be smart**
  - Lock to multiple sources simultaneously
  - Switch between them with phase and frequency buildout



Summary

- **The move to "time everywhere" poses a big problem for holdover**

- **Holdover is expensive …**
  - Money
  - Space
  - Power

- **We should get smart**
  - Can we use multiple sync sources instead?
  - Can we restrict holdover to specific locations?
  - Can we reduce the holdover period?
  - What holdover performance do we really need?

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Thank You!

Questions?