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Network Time Distribution for Small Cells

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WSTS, April 16, 2013

Agenda

- How hard can it be?
- Satellite Time Distribution
- Network Time Distribution
- Combining the Two

How hard can it be?

Performance Target Specifications

Application	Frequency: Network / Air Interface	Time
UMTS / LTE FDD Small Cell	NA / 100 – 250 ppb	Not required
GSM / UMTS / W-CDMA		Not required
CDMA2000		± 3 to 10 µs
TD-SCDMA		± 1.25 µs (sync interface) ±1.5 µs (air interface)
LTE – FDD		Not required
LTE – TDD	16 ppb / 50 ppb	± 1.5 µs (≤3 km cell radius) ±5 µs (>3km cell radius)
LTE – CSFB to CDMA2000		± 10 µs
LTE-A MBSFN		± 1 µs inter-cell phase difference*
LTE-A Hetnet Coordination (eICIC)		± 5 µs inter-cell phase difference*
LTE-A CoMP (Network MIMO)		± 0.5 µs inter-cell phase difference*
Handset Location to 100m (E911)		± 100 ns

** Vendor specific figures, no 3GPP specification*

Contributions to UTC

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CIRCULAR T 302 ISSN 1143-1393
2013 MARCH 08, 10h UTC

BUREAU INTERNATIONAL DES POIDS ET MESURES
ORGANISATION INTERGOUVERNEMENTALE DE LA CONVENTION DU METRE
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1 - Coordinated Universal Time UTC and its local realizations UTC(k). Computed values of [UTC-UTC(k)] and uncertainties valid for the period of this Circular.
From 2012 July 1, 0h UTC, TAI-UTC = 35 s.

Date 2013 0h UTC	JAN 27	FEB 1	FEB 6	FEB 11	FEB 16	FEB 21	FEB 26	Uncertainty/ns			Notes
MJD	56319	56324	56329	56334	56339	56344	56349	uA	uB	u	
Laboratory k				[UTC-UTC(k)]/ns							
AOS (Borowiec)	-8.0	-8.7	-9.7	-10.7	-10.4	-10.6	-10.9	0.3	5.2	5.3	
APL (Laurel)	3.2	3.5	3.3	-0.8	-2.0	-2.9	-2.5	0.3	5.2	5.3	
AUS (Sydney)	415.6	416.1	414.0	413.5	409.1	403.9	406.1	0.3	5.2	5.2	
BEV (Wien)	-39.5	-44.8	-59.5	-71.3	-58.4	-48.5	-48.3	0.3	3.4	3.4	
BIM (Sofiya)	1890.8	1905.3	1924.2	1937.9	88.5	95.3	91.4	1.5	7.2	7.3	(1)
BIRM (Beijing)	206.5	210.8	213.5	222.5	220.3	214.7	216.8	1.5	20.1	20.1	
BY (Minsk)	-38.4	-34.2	-34.4	-32.3	-27.8	-28.2	-27.5	1.5	7.2	7.3	
CAO (Cagliari)	-	-	-	-	-	-	-				
CH (Bern-Wabern)	5.2	0.0	-5.5	-3.6	3.7	7.1	13.6	0.3	1.9	1.9	
CNM (Queretaro)	-19.1	-17.0	-10.7	-14.1	-12.7	-12.9	-10.2	2.0	5.2	5.6	
CNMP (Panama)	-24.6	-13.6	-15.0	-11.7	-19.6	-25.0	-34.6	3.5	5.2	6.2	
DLR (Oberpfaffenhofen)	39.6	39.9	35.9	25.9	16.2	1.2	1.3	0.7	5.2	5.3	
DMDM (Belgrade)	9.7	20.1	15.9	7.7	-6.1	-8.2	-9.1	0.3	7.1	7.2	
DTAG (Frankfurt/M)	303.9	291.6	292.6	295.6	286.6	276.2	266.5	0.3	10.1	10.1	
EIM (Thessaloniki)	-	-	-	-	-	-	-				
ESTC (Noordwijk)	-47.2	5.3	3.0	-0.1	-0.5	0.1	-2.1	0.7	20.1	20.1	(2)
HKO (Hong Kong)	881.2	902.5	920.9	932.0	952.1	963.6	977.8	2.5	5.2	5.8	
IFAG (Wettzell)	-590.3	-594.8	-591.9	-597.1	-603.9	-610.2	-615.6	0.3	5.2	5.2	
IGNA (Buenos Aires)	11002.6	11069.3	11138.0	11194.4	11255.7	11311.9	113[illegible]7.5	2.0	5.2	5.6	
INPL (Jerusalem)	-181.4	-185.9	-196.2	-209.3	-216.7	-224.6	-224.9	0.7	19.9	19.9	
INTI (Buenos Aires)	43.9	22.1	22.1	2.7	-12.4	-16.3	-5.6	4.0	20.1	20.5	
INXE (Rio de Janeiro)	-24.7	-17.2	-14.8	-14.0	-9.4	-6.2	-3.6	0.3	20.1	20.1	
IPQ (Caparica)	-	-	-	-	-	-	-				
IT (Torino)	-11.1	-10.6	-10.1	-9.3	-7.6	-6.6	-5.3	0.3	2.0	2.0	
JATC (Lintong)	-5.4	-4.3	-4.9	-5.6	-4.3	-2.5	-2.7	0.5	5.1	5.1	
JV (Kjeller)	338.4	377.6	374.3	391.5	389.4	394.5	373.5	5.0	20.0	20.6	
KEBS (Nairobi)	378.0	471.1	577.0	687.1	781.4	893.0	989.5	1.5	20.1	20.1	
KIM (Serpong-Tangerang)	301.1	-	-	-	-	-	-	2.0	20.1	20.2	
KRIS (Daejeon)	31.9	28.3	23.5	18.2	14.1	10.0	6.7	0.3	5.1	5.1	

Uncertainty up to 20ns

Offset up to 11µs

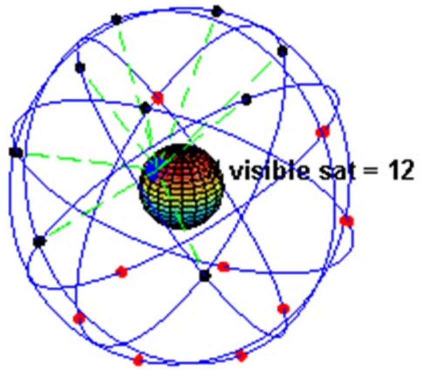
How long can you hold a microsecond?

- PRS (Primary Reference Source)
  - Frequency accuracy = 1×10^{-11} (G.811 specification)
  - Holds 1µs for 100,000s (~28 hours)
- Cesium clock
  - Typical frequency accuracy = 5×10^{-13}
  - Holds 1µs for 2,000,000s (~23 days)
- Rubidium clock
  - Drift under temperature cycling ~1.5µs in 24 hours
- Good quality OCXO
  - Drift under temperature cycling ~8µs in 24 hours

Do not squander time!

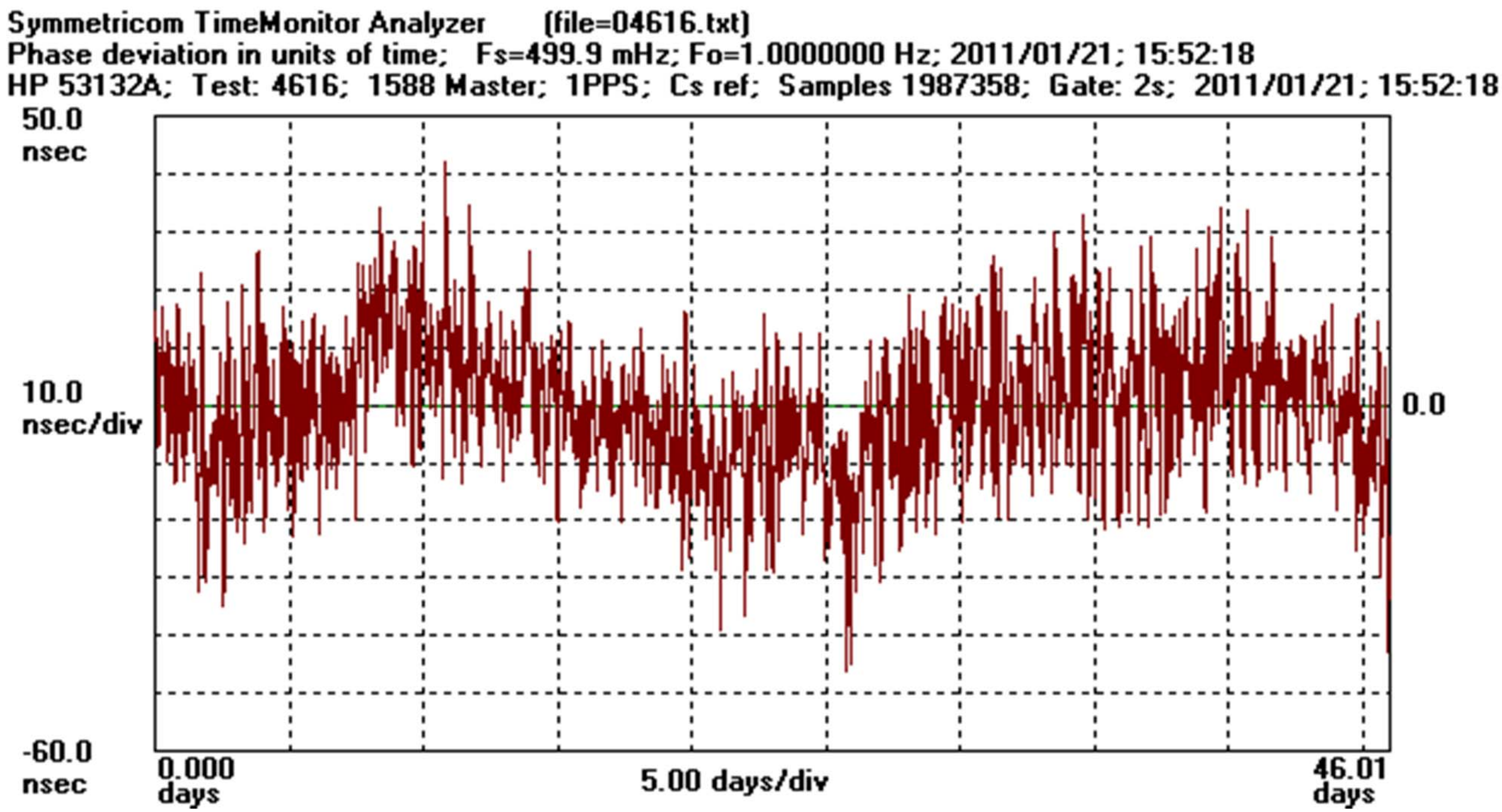
Satellite Time Distribution

Satellite Time Distribution (GNSS)



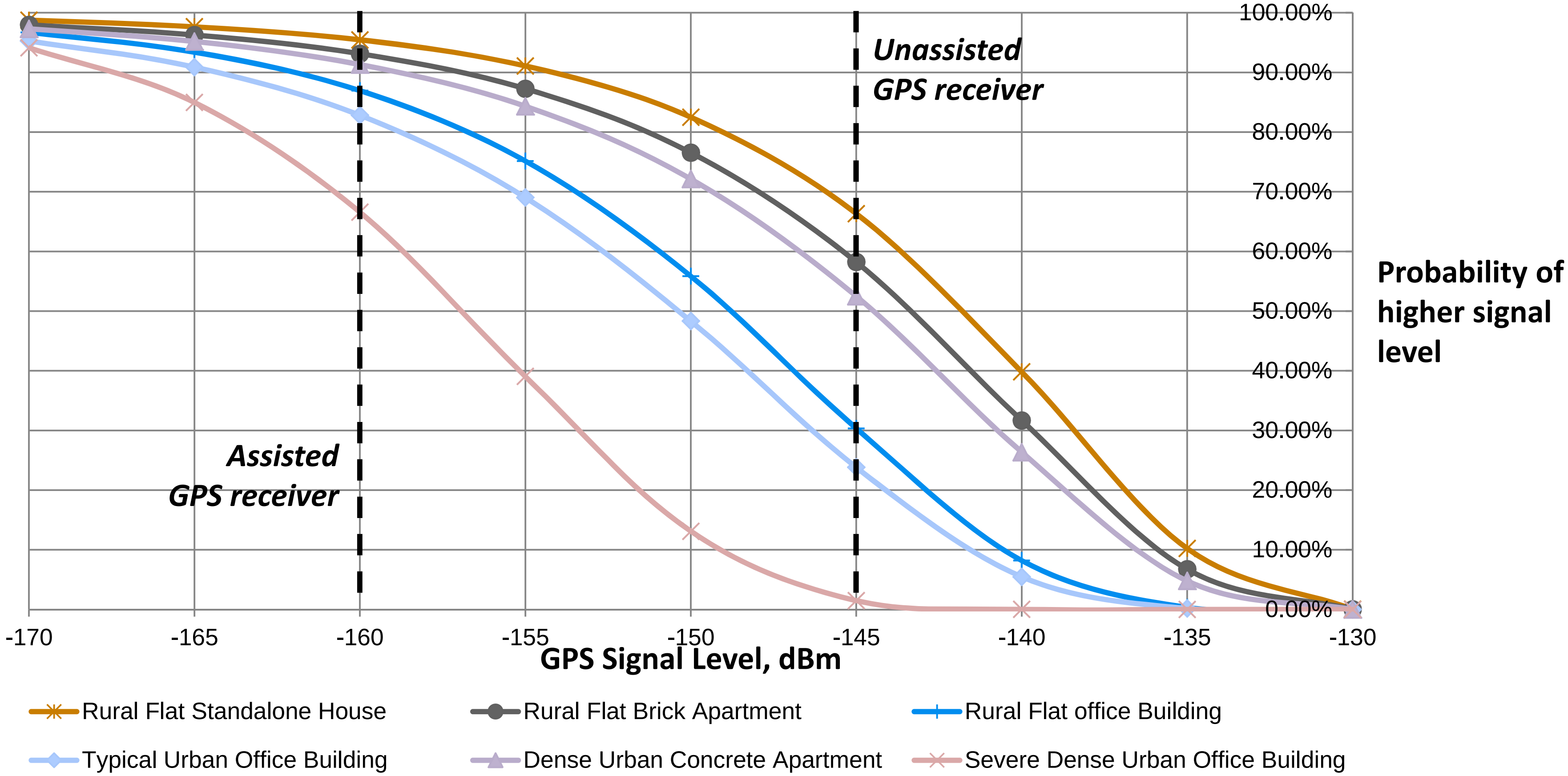
- Time distributed by radio from satellite
- Typical accuracy: < 100ns
- Advantages:
  - Global availability (provided there is a clear view of the sky)
  - Accuracy
  - System reliability
- Disadvantages:
  - Clear view of sky may not be available
  - Vulnerability to interference from ground based transmissions
  - Antenna issues – wind, rain, snow, ice, corrosion, bullets!
  - Political issues

Long Term GPS Performance



In-Building Reception

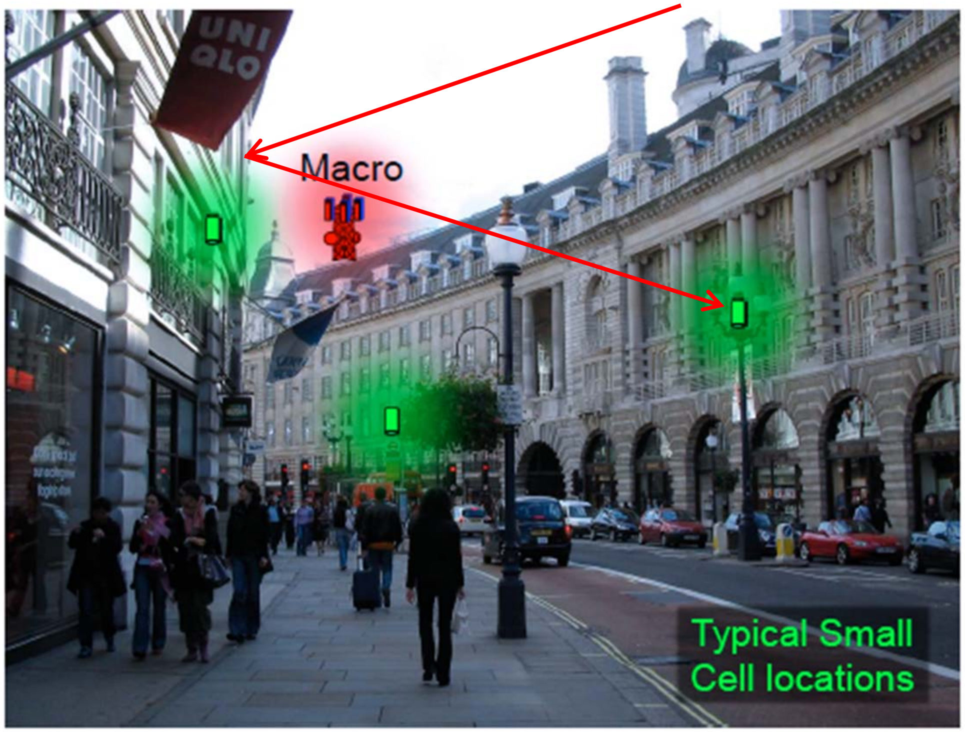
- Signal strength at earth surface around -130dBm
- Buildings may attenuate this by over 40dB

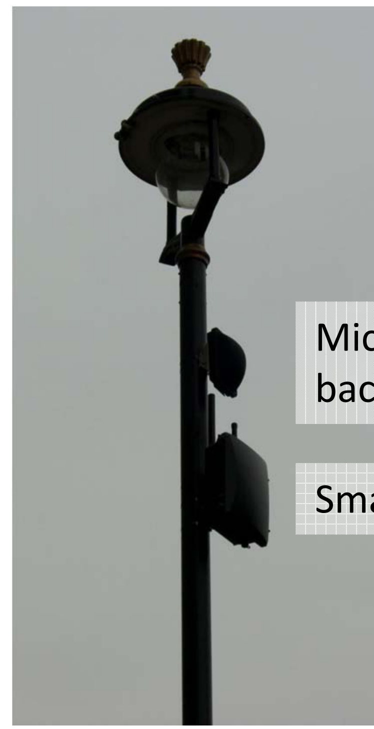


Graph adapted from Small Cell Forum white paper "Femtocell Synchronization and Location", May 2012

Urban Canyons

- May not be able to view sufficient satellites all of the time
  - Intermittent fixes
- Multi-path reflections distort range measurements
  - Path length change of 30m = time change of 100ns





Pictures from Telefonica wi-fi small cell trial, London, summer 2012

Interference and Jamming

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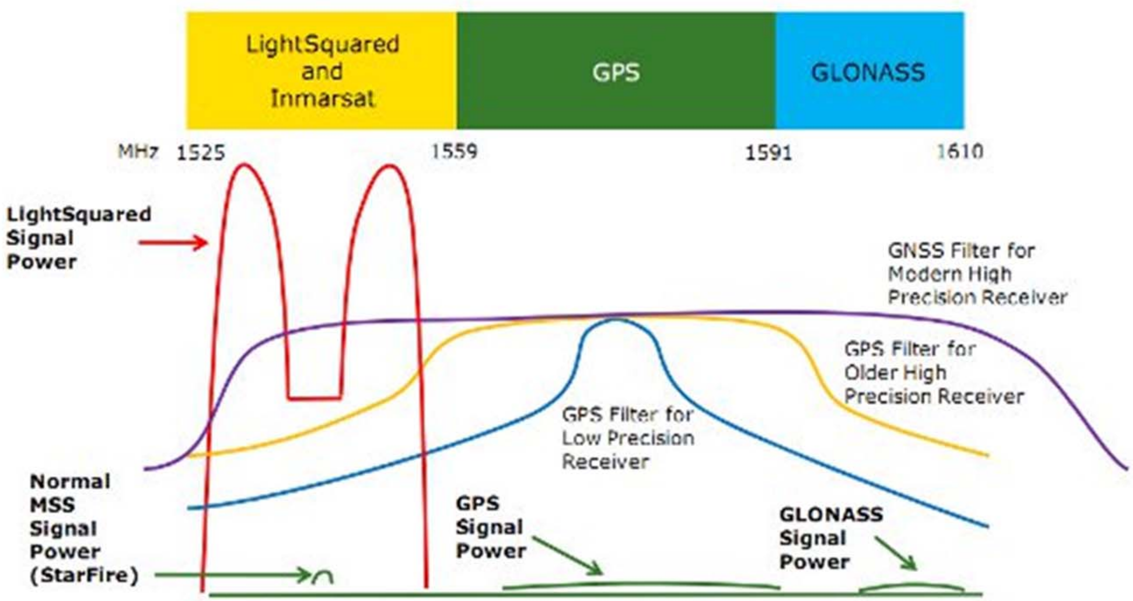
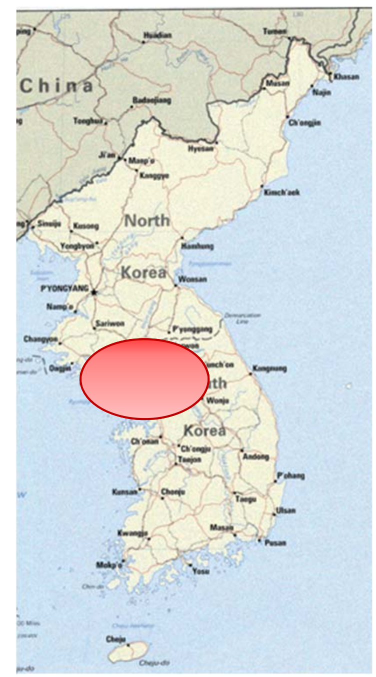
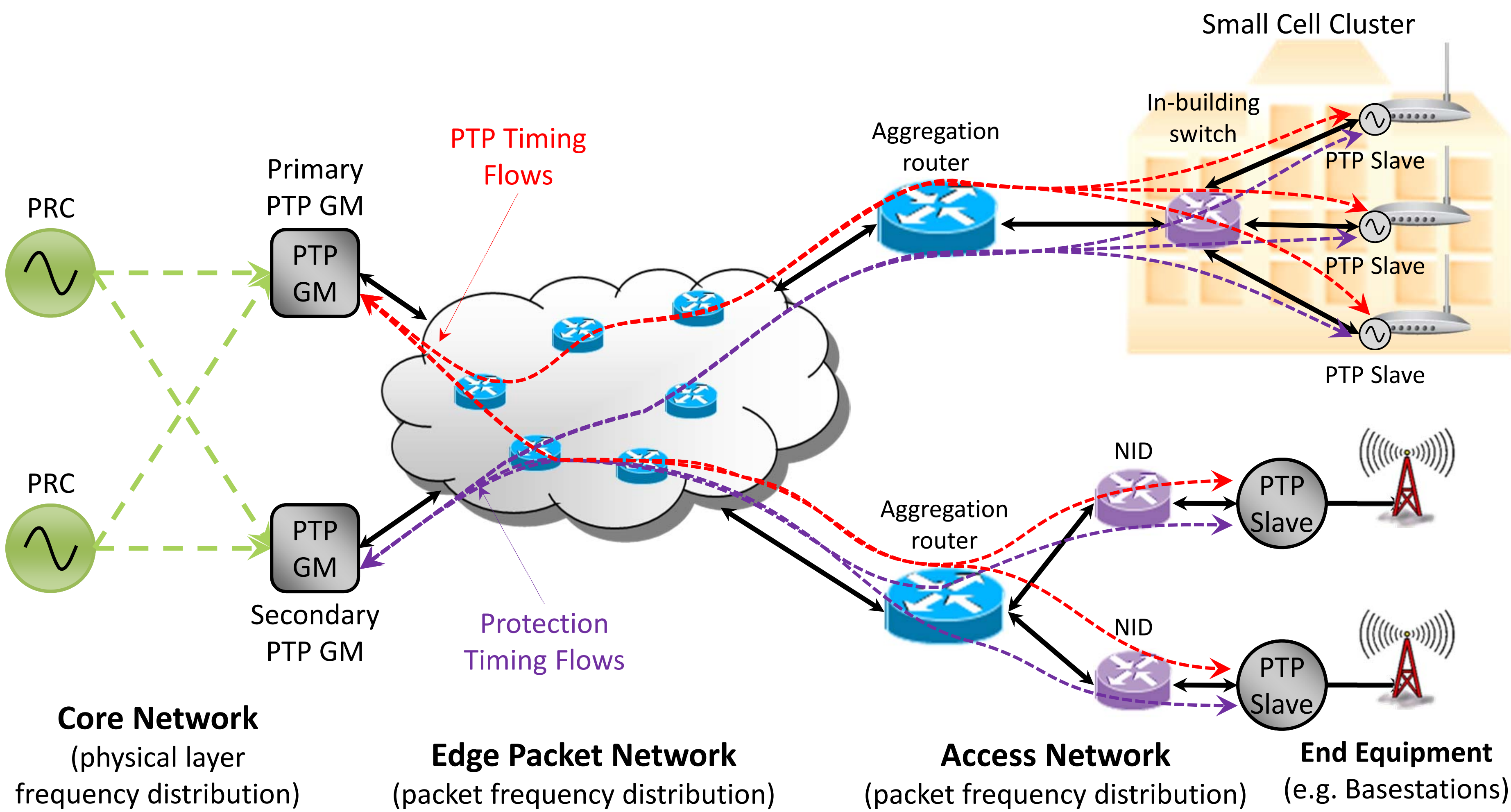
- Doesn't take much to jam a -130dBm signal!
  - Personal jammers
  - Legal terrestrial transmissions,
    e.g. Light Squared (now closed down)
  - Political jamming, e.g. North Korea



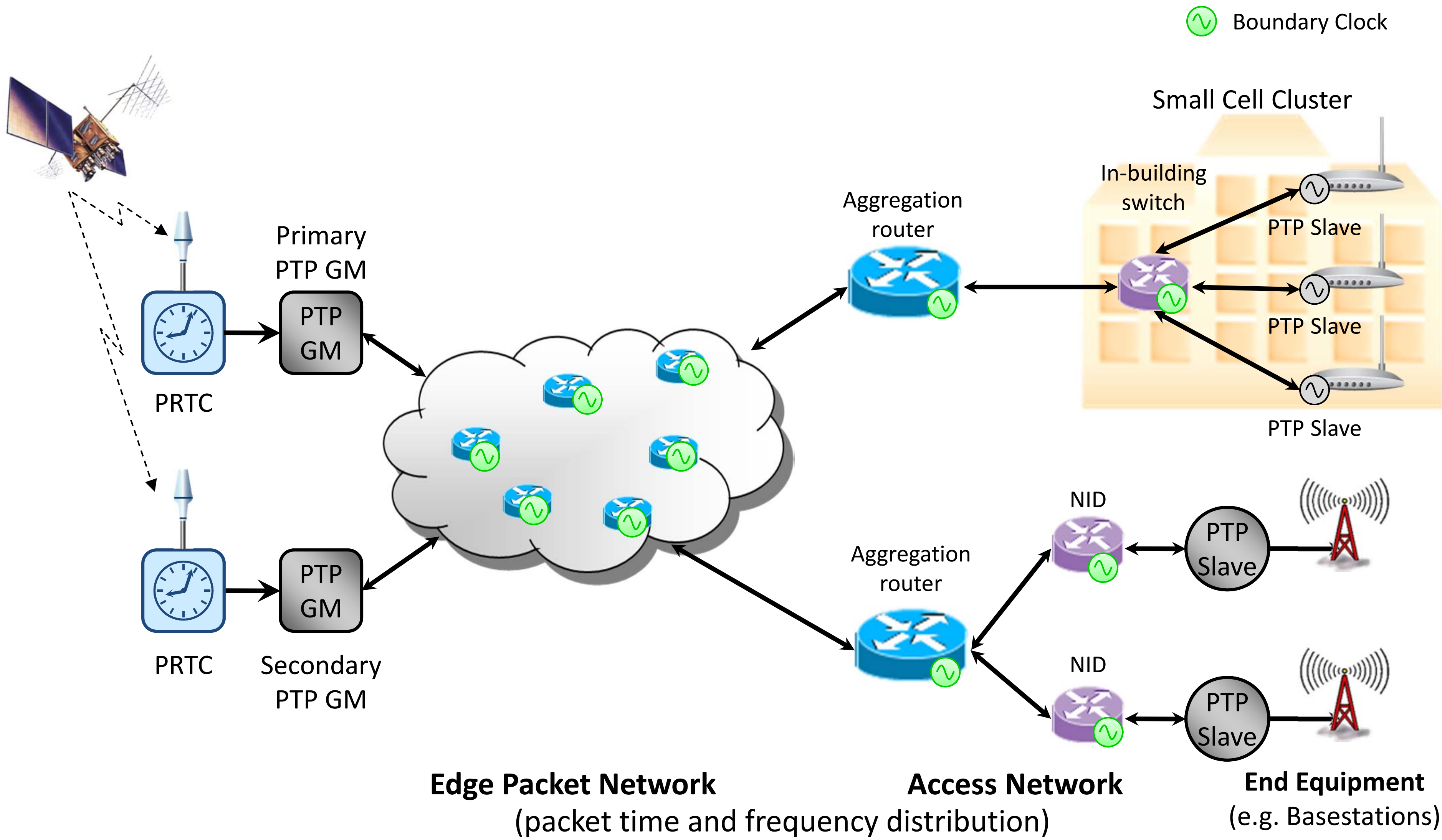


Network Timing Distribution

G.8265 Architecture: Expanded view



G.8275.1 Profile: Full Timing Support



G.8275.1 Profile: Universal Boundary Clocks

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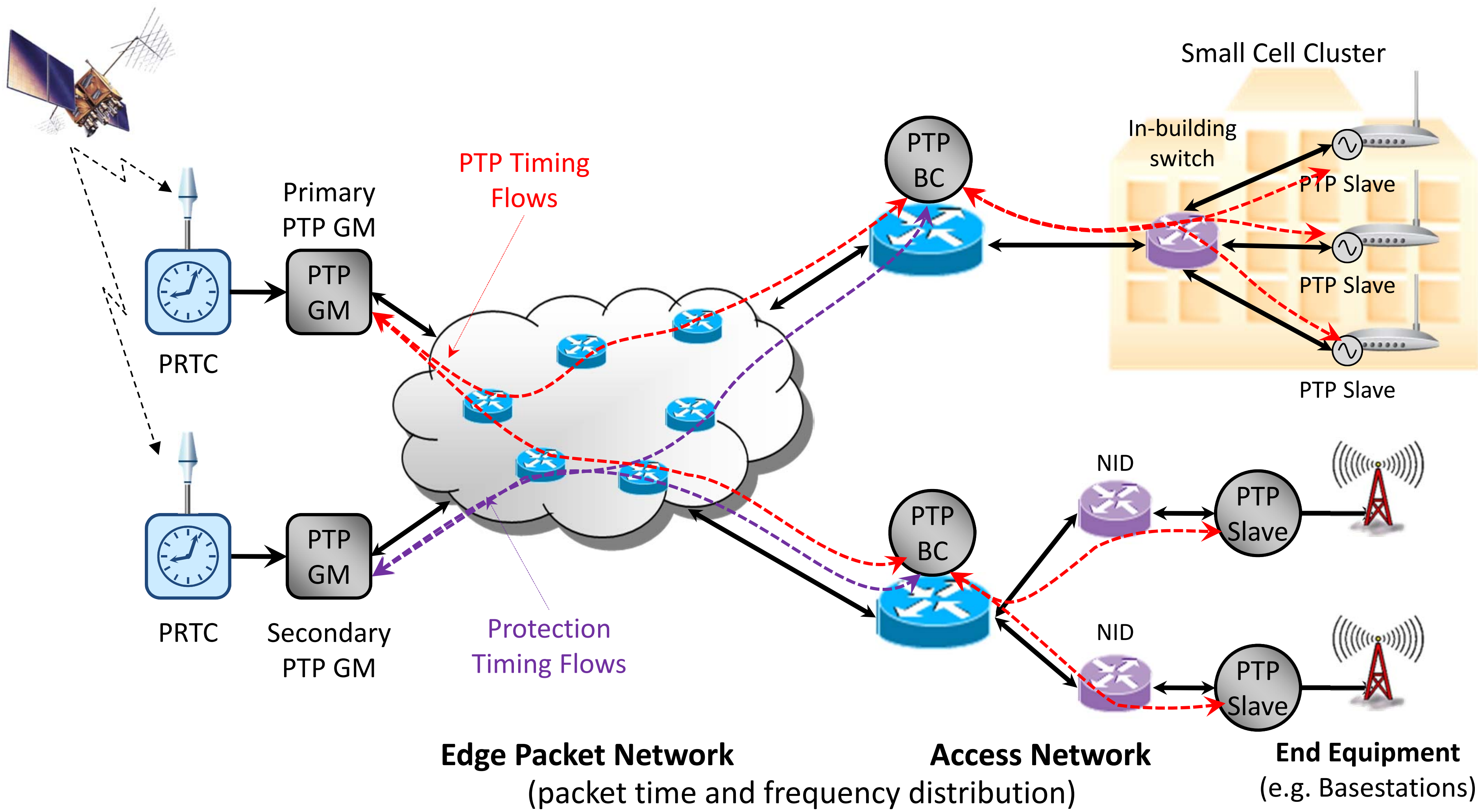
- Boundary clocks very simple
  - Rely on SyncE for stability
  - BC just a simple protocol add-on to the switch/router function
  - Transparent Clocks (TCs) not considered in this version
- No upgrade path from G.8265 frequency architecture
  - Protection and master selection based on BMCA, not G.781
    - G.8265.1 slaves not compatible
- Requires upgrade of entire transmission path
  - Typically deployed in green-field sites, or where no packet-based frequency sync has been deployed
- Doesn't solve the time offset caused by link asymmetry
  - Fibers are manually calibrated in existing deployments

G.8275.2 Profile: Partial Timing Support

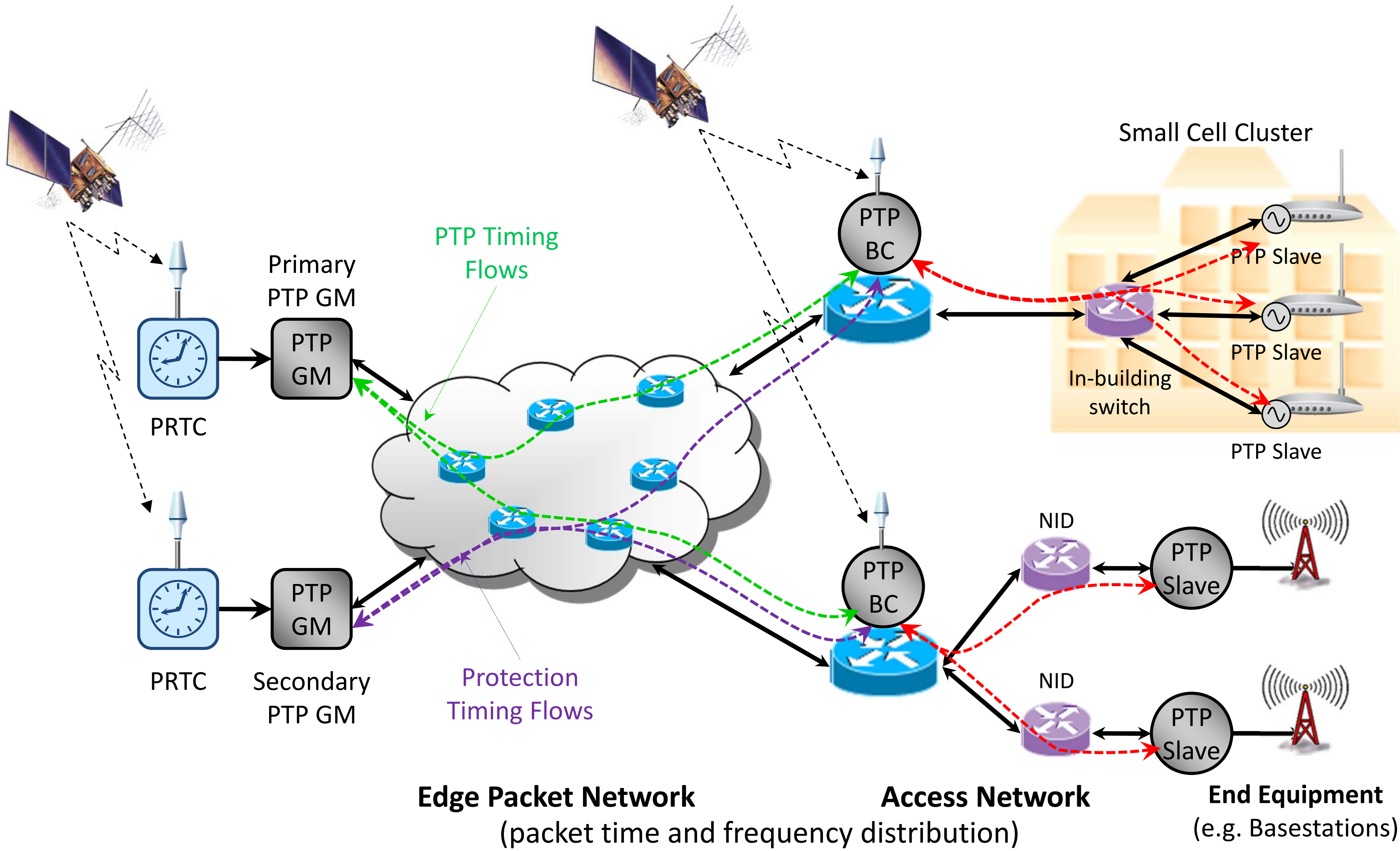


G.8275.2 Profile: Segmented Architecture

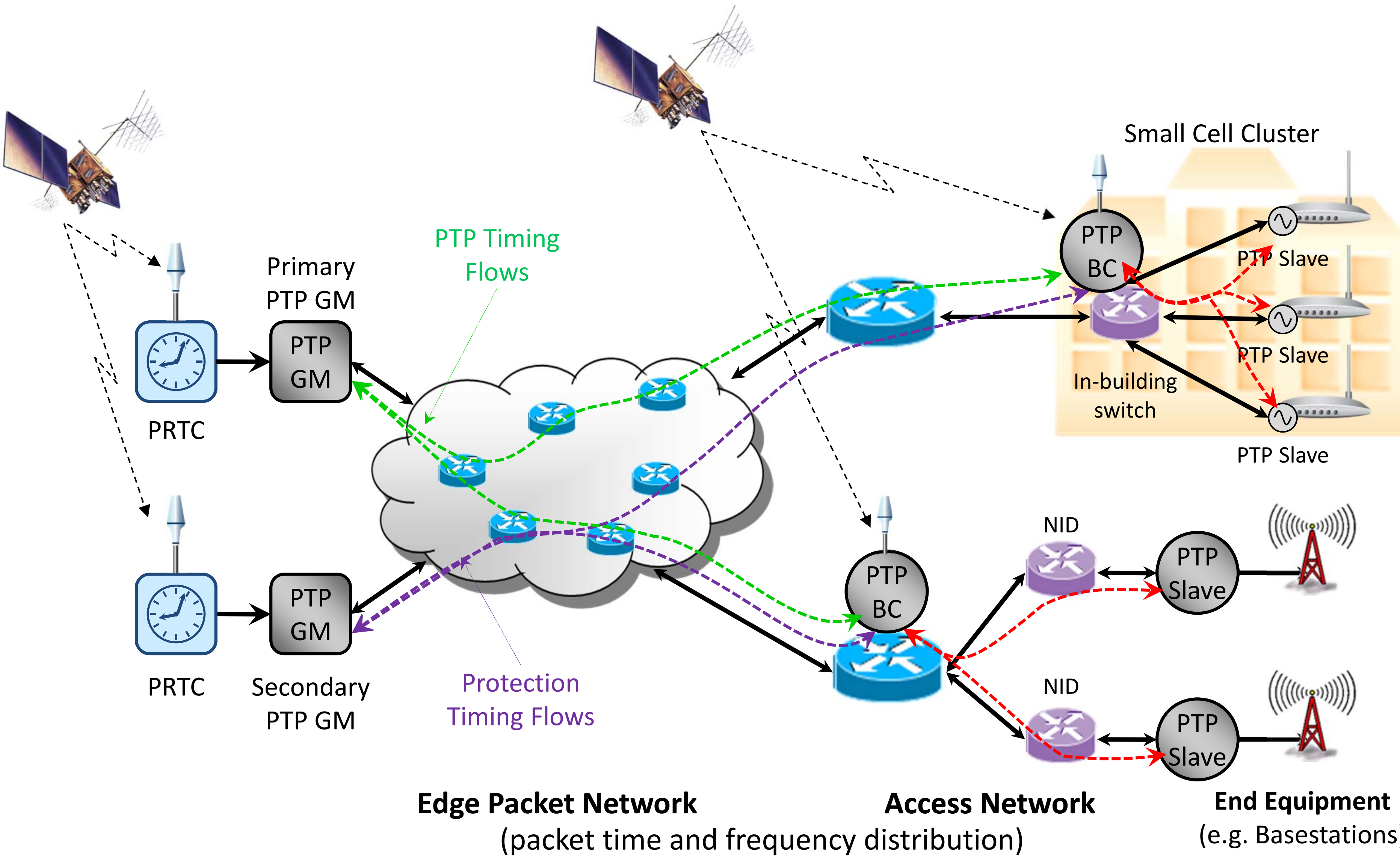
- Strategically-placed BCs break timing path into segments
  - Simple network upgrade from Frequency Profile
  - Re-uses existing PTP GMs and Slaves
- Doesn't require intermediate on-path timing support
  - Allows operation over existing deployed networks
- Requires intelligent boundary and slave clocks
  - Intelligent algorithms filter out the packet delay variation
  - Clocks combine sync from any available source
    - PTP, SyncE, SDH, GPS etc.
  - BCs can be implemented as a standalone box

Combining the two

Distributed GPS with PTP backup



Move GPS as close as possible to cells



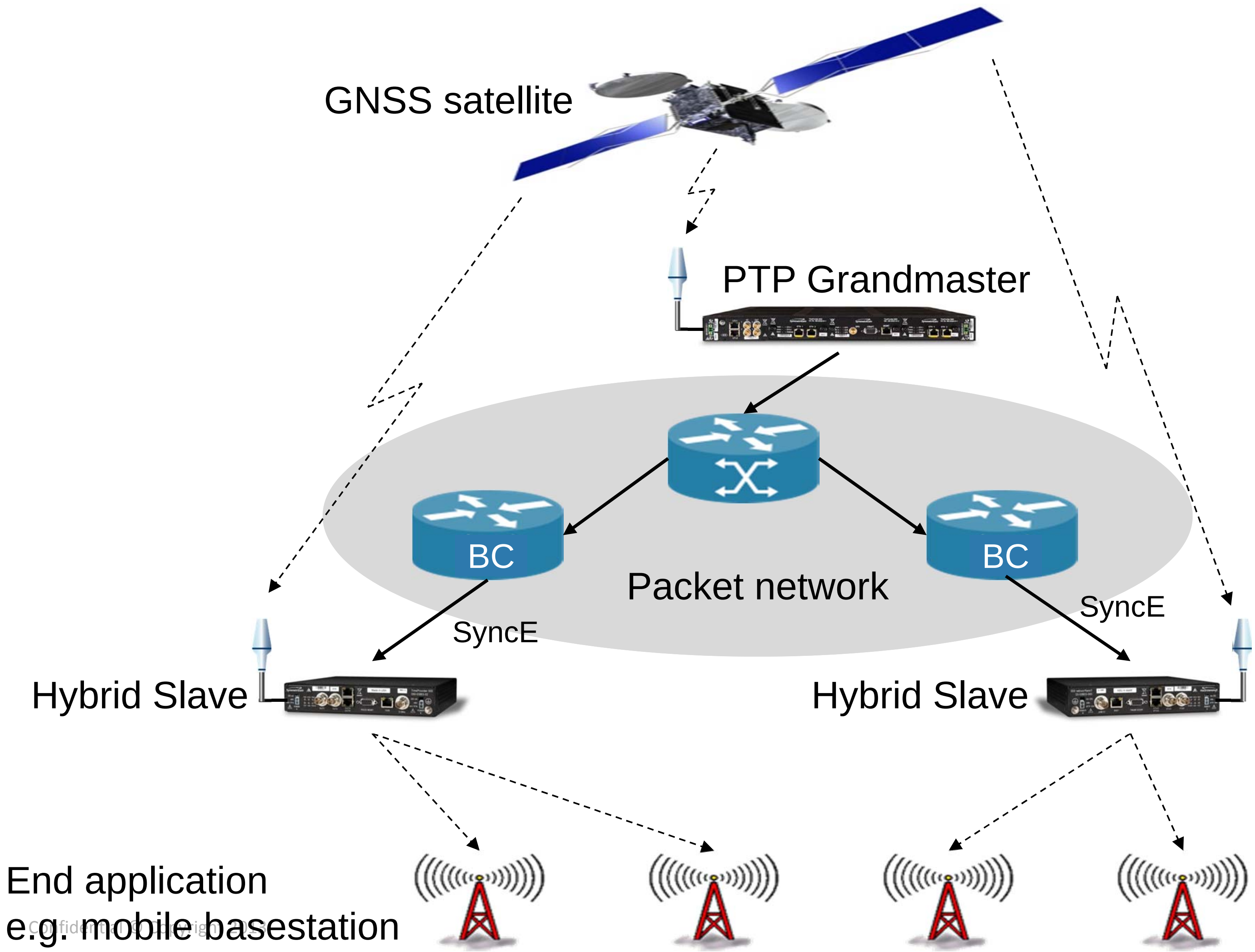
Improving GNSS Detection and Acquisition

- Assisted GPS (AGPS) uses information from the network to assist in demodulating the GPS signal
  - Ephemeris data describes where each satellite is at any given time
- Time fix from PTP (to within a ms)
  - Allows GPS signal to be acquired at lower signal to noise ratio
- Position fix (e.g. from local survey)
  - Base stations typically don't move!
  - Known position also allows the signal to be acquired at a lower SNR
- Coherent Integration
  - Stable frequency allows GPS signal to be integrated for longer, improving acquisition
  - SyncE allows integration times of ≈5s, similar to a good TCXO
  - OCXO or Rb oscillator will allow longer integration times

Maintaining time between GNSS fixes

- In urban canyons or in buildings, fixes may be several minutes apart
- Local interference or jamming may temporarily interrupt GNSS service
- Timebase maintained using stable frequency
  - OCXO will maintain 1µs for around 60s (variable temp)
  - SyncE will maintain 1µs phase for around 2000s
  - Rb oscillator will maintain 1µs for nearly 24 hours (variable temp)
- Timebase maintained using PTP
  - PTP will maintain phase indefinitely
  - GNSS time fix can be used to calibrate the asymmetry
  - Measures asymmetry on a “whole of network” basis

Hybrid PTP/GPS/SyncE solution



Hybrid PTP/SyncE/GNSS Solution

- Advantages
  - Initial PTP time fix allows acquisition of GNSS signal at lower power
  - SyncE or oscillator stability allows longer coherent integration
  - Accurate GPS time allows calibration of overall PTP asymmetry
  - PTP provides backup in event of GNSS failure

- Disadvantages
  - Requires installation of multiple infrastructures

Conclusions

Conclusions

- Several commercial applications require time accuracy well below 1μs
- No single technique is a complete solution to this:
  - GNSS
  - PTP
  - SyncE
  - Advanced oscillators
    - modern temperature compensation techniques
    - miniature atomics (Rb and Cs)
- Hybrid techniques addresses the deficiencies of each
  - Creates an accurate, robust solution for precise time distribution
  - At least two are required for a reliable solution (GNSS + 1 other)

Thank You

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