

# Mobile Network Requirements: Manufacturer's Perspective

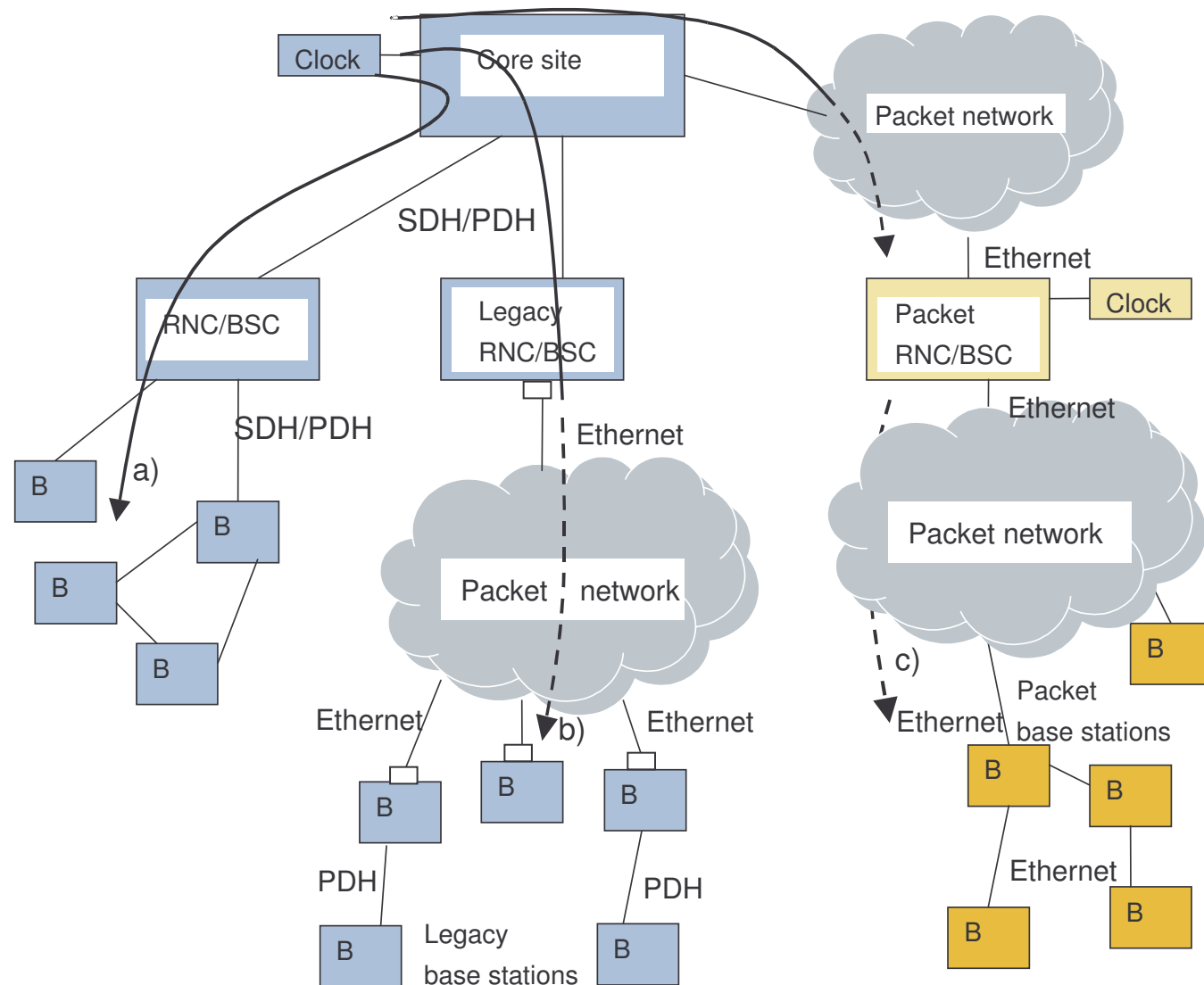
Antti Pietiläinen, Nokia Research Center

# Cellular network evolution

- At present, PDH E1s (2048 kbit/s) and T1s (1544 kbit/s) carry backhaul of GSM/UMTS base stations.
- New high bit rate services have the potential of increasing backhaul bandwidth significantly.
- Ethernet may provide cost effective means to increase the bandwidth.
- Two synchronization problems arise
  - How to synchronize remaining PDH interfaces?
  - How to synchronize air interface and data clock?

# Migration to packet networks, a scenario

- a) High-quality clock is distributed across the SDH/PDH network.
- b) Packet network is introduced. Legacy base stations should work.
- c) RNC/BSC and base stations support packet transport.



# PDH/SDH requirements

- ITU-T recommendations set limits on the magnitude of jitter and wander at network interfaces to avoid generation of bit errors, uncontrolled slips and other abnormalities and for proper design of the equipment.
- The wander may not exceed the given values anywhere in the network. Thus, a circuit emulation link, for example, may consume only part of the wander budget.

G.824 – MTIE (maximum time interval error) limits of synchronous network interface for 1544 kbit/s rate.

Observation interval ( $\tau$ ) in seconds	MTIE in $\mu\text{s}$
$\tau \leq 900$	8.4
$900 < \tau \leq 86\,400$	18

# GSM and WCDMA requirements

## GSM: 3GPP TS 45.010

- The BTS shall use a single frequency source of absolute accuracy better than 0.05 ppm for both RF frequency generation and clocking the timebase. The same source shall be used for all carriers of the BTS.
- For the pico BTS class the absolute accuracy requirement is relaxed to 0.1 ppm

## WCDMA: 3GPP TS 25.104

- The same source shall be used for RF frequency and data clock generation.
- The modulated carrier frequency of the BS shall be accurate to within the accuracy range observed over a period of one timeslot.

<b>BS class</b>	<b>Accuracy</b>
Wide Area BS (all BSs until Release 5)	$\pm 0.05$ ppm
Medium Range BS (Introduced in Release 6)	$\pm 0.1$ ppm
Local Area BS (Introduced in Release 6)	$\pm 0.1$ ppm

## Some reasoning behind the requirements

- The mobile must be able to successfully decode signals with frequency offset.
- Largest offset is caused by Doppler shift. The frequency error of the base stations adds to the Doppler shift.
- If maximum allowed velocity is decreased, the base station offset can be relaxed.
- However, too large relaxation to base station offset may cause some problems with mobiles. Therefore, the maximum error of local area base stations is limited to 0.1 ppm – leading to relatively high allowed velocity.

Type		GSM 900 MHz	GSM 1800 MHz	WCDMA 2100 MHz
Mobile must tolerate offset		295 Hz	340 Hz	591 Hz
Wide	Velocity & Doppler	250 km/h & 250 Hz	130 km/h & 250 Hz	250 km/h & 486 Hz
	0.05 ppm contrib.	45 Hz	90 Hz	105 Hz
Local	Velocity & Doppler	205 km/h & 205 Hz	80 km/h & 160 Hz	196 km/h & 381 Hz
	0.1 ppm contrib.	90 Hz	180 Hz	210 Hz

# WiMAX and 3.9 G

## WiMAX

- Unsynchronized OFDMA (orthogonal frequency division multiple access) PHY requires 2-ppm frequency accuracy.
- Frequency synchronized OFDMA PHY requires an accuracy of a few ppb. The exact values vary with, for example, FFT size and channel bandwidth.

3.9G will probably require similar stability as GSM/WCDMA

- 0.05-ppm frequency stability in wide-area base station
- 0.1-ppm frequency stability in local-area base station

# Time synchronization

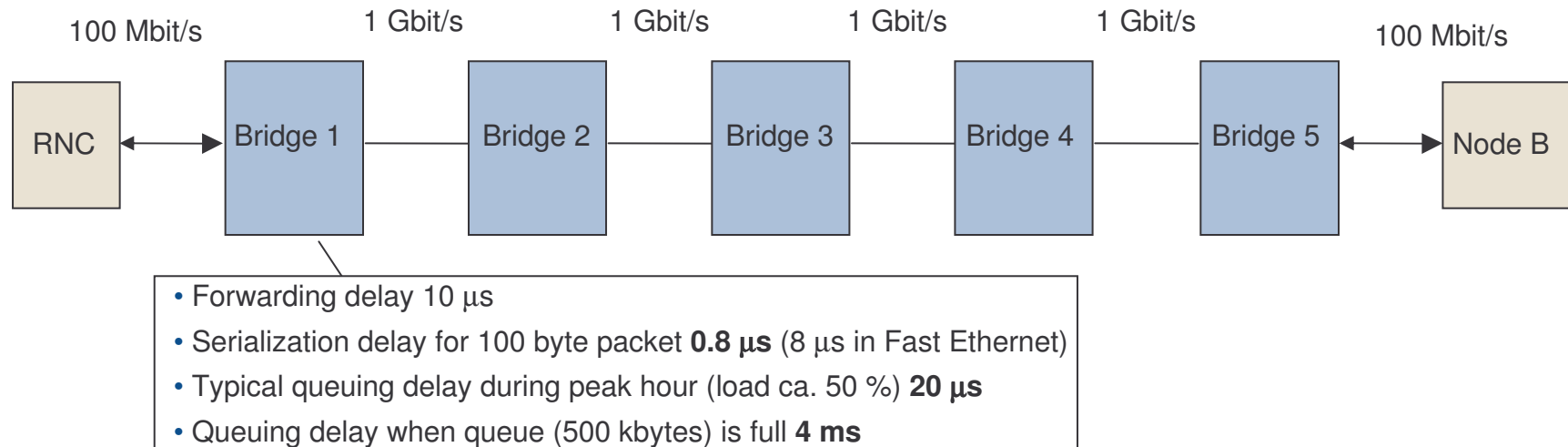
- CDMA2000 requires time synchronization at  $\pm 3 \mu\text{s}$  ( $\pm 10 \mu\text{s}$  worst case) .
- WCDMA TDD mode requires 2.5- $\mu\text{s}$  time accuracy between neighboring base stations (i.e.  $\pm 1.25 \mu\text{s}$  of UTC). At present, WCDMA TDD has not been implemented.
- 3.9G may require time synchronization, at 1-ms or better accuracy (even 1-us level).
- WiMAX (802.16): Time synchronized OFDMA PHY requires an accuracy of a few microseconds. The exact values vary with, for example, FFT size and channel bandwidth.
- Location determination typically requires time synchronization

# Synchronization by timing packets

- Frequency traceable to a primary reference clock can be reconstructed at a base station by sending timing packets from the primary reference clock to the base station.
- A residual uncertainty of 1 ms in packet delay converts into a frequency uncertainty of 0.05 ppm if timing packets are averaged for a duration of 20 000 seconds.
- During this time the wander of the local oscillator must be a small fraction of the 0.05-ppm budget.

# Packet network delay

- Well behaving network
  - Gigabit switches
  - Fast Ethernet at end points

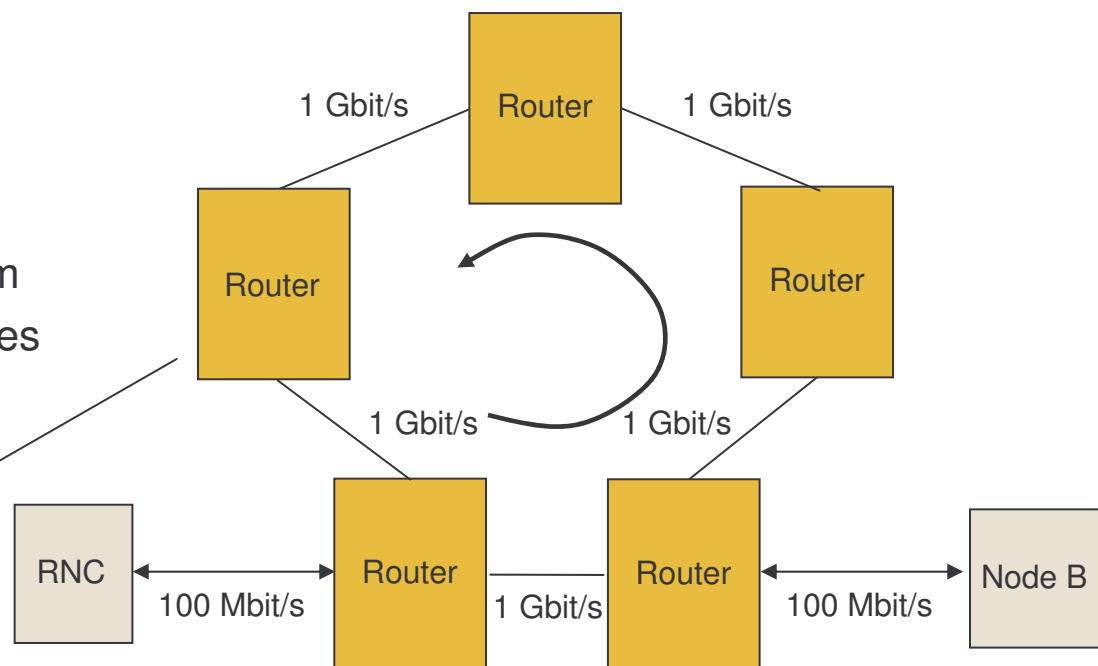


- Delay (excluding flight time)
  - Minimum  $(8 + 4 \times 0.8 + 5 \times 10 + 8) \mu$ s = 70  $\mu$ s
  - Typical peak hour  $[8 + 4 \times (0.8 + 20) + 5 \times 10 + 8] \mu$ s = 150  $\mu$ s
  - Maximum  $4 \times 4$  ms = 16 ms

# Packet network delay

- More difficult network

- Gigabit routers, but:
- Different route up and downstream
- Delay changes when route changes



- Forwarding delay typically  $10 \mu\text{s}$
- Serialization delay for 100 byte packet  **$0.8 \mu\text{s}$**  ( $8 \mu\text{s}$  in Fast Ethernet)
- Typical queuing delay during peak hour (load ca. 50 %)  **$20 \mu\text{s}$**
- Queuing delay when queue (50 Mbytes) full  **$400 \text{ms}$**

- Delay (excluding flight time)

- Minimum  $(8 + 0.8 + 2 \times 10 + 8) \mu\text{s} = 40 \mu\text{s}$
- Typical peak hour downstream  $(8 + 0.8 + 20 + 2 \times 10 + 8) \mu\text{s} = 60 \mu\text{s}$
- Typical peak hour upstream  $[8 + 4 \times (0.8 + 20) + 5 \times 10 + 8] \mu\text{s} = 150 \mu\text{s}$
- Maximum downstream  $1 \times 400 \text{ms} = 400 \text{ms}$ !
- Maximum upstream  $4 \times 400 \text{ms} = 1600 \text{ms}$ !

# Observations

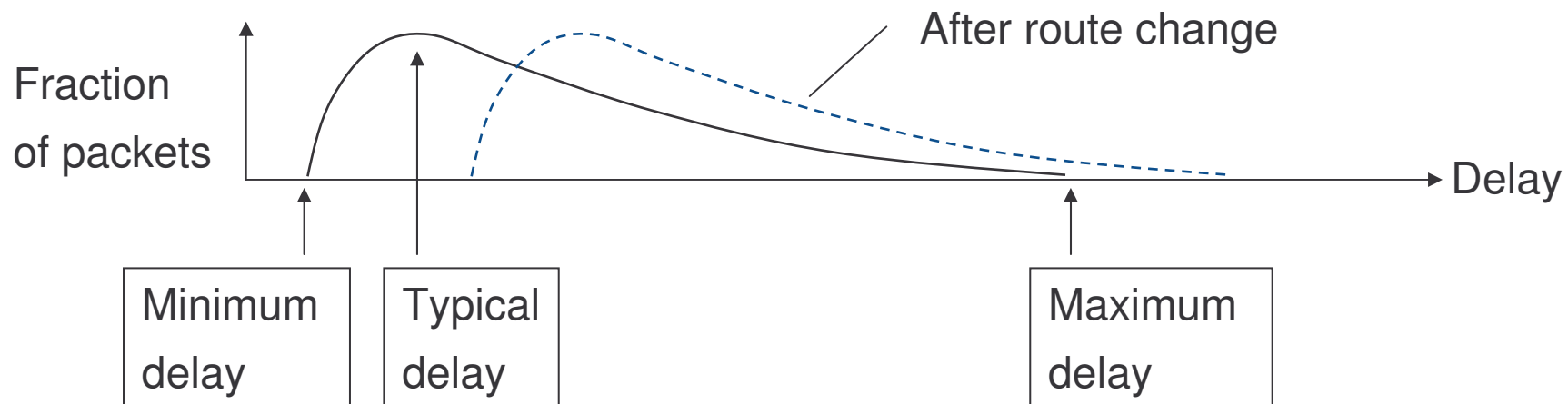
- Typical delay variation in a relatively small, high-speed network is on the order of 100  $\mu$ s, which is acceptable for pursuing 0.05-ppm accuracy.
- During severe network congestion, delays may become very long because queuing buffers of routers are large.
  - Is the only solution to priority tag timing packets?

# How to define service level agreement SLA?

- An SLA might state, for example:

Service class	Delay	Delay jitter	Packet loss
Premium	99 % < 5 ms	99 % < 1 ms	0.01 %
Silver	95 % < 5 ms	N/A	0.01 %
Bronze	95 % < 15 ms	N/A	0.1 %

- However, for synchronization purposes it may be more important to know how stable is the typical or minimum delay value.



# Observations

- SLA class definitions and requirements for packet timing might not coincide.
  - New definitions may be required in SLAs
- Route changes may be difficult to handle.
  - However, in a relatively small network, this may occur very seldom. → Is it acceptable to be slightly out of sync specs for some time after a rare event ?

# Timing standards

- **NTP** is already widely implemented. Free-of-charge code is available.
  - NTP v. 4 under works
- **IEEE1588** specifies hardware time stamping and can therefore provide not only frequency synchronization but also extreme time accuracy.
  - Version 2 supporting telecom under development
  - In large networks, which incorporate time protocol agnostic switches, IEEE1588 does not bring any clear advantage over NTP.
- **G.pactiming** will specify synchronization requirements for circuit emulation service over Ethernet.

# Observations

- For achieving microsecond time accuracy end to end, intermediate nodes need to support synchronization at hardware level.
  - For packet transport service providers cellular operators are important customers but the majority of revenue comes elsewhere.
    - An operator will not upgrade all network nodes to be e.g. IEEE1588 compliant unless
      - The cost increase is marginal.
      - The operator can expect increased revenue from the customers by providing accurate timing service.
- Time synchronized systems will need GPS receivers forever?
- The number of features being introduced into IEEE 1588 is increasing endlessly. Some features might not be required by cellular networks; examples:
    - Fault tolerance: Equipment protection and network protection can be used instead to achieve adequate robustness.
    - Security: There are other means to protect operator traffic from outsiders so this application layer security feature may not be needed.
    - PTP protocol over MPLS: Increases complexity but brings only marginal increase in performance.

# Conclusions

- Three requirement levels have been introduced
  1. 50-ppb frequency accuracy at RF interface
    - Adequate for packet based GSM, WCDMA, and possibly 3.9 G base stations
    - Can be packet timed at relatively low cost.
  2. G.823/G.824 wander mask - For example max. 18- $\mu$ s during 24 hours at traffic interface
    - Required by legacy equipment that are served by a packet network.
    - Can be packet timed at acceptable cost.
  3. *Time* synchronized
    - WCDMA TDD, WiMAX TDD, 3.9 G
    - Impossible in wide-area network without GPS receiver ?
- A packet timing standard is required. Proprietary technologies do not live long. IEEE1588 is a good candidate because it provides the same as NTP - plus added accuracy in a standard compliant network.
- Timing solution and mobile network vendors need to define together the SLA parameters, which ensure specified performance of the mobile network.