IEEE 1588 in Mobile Networks – Migration scenario

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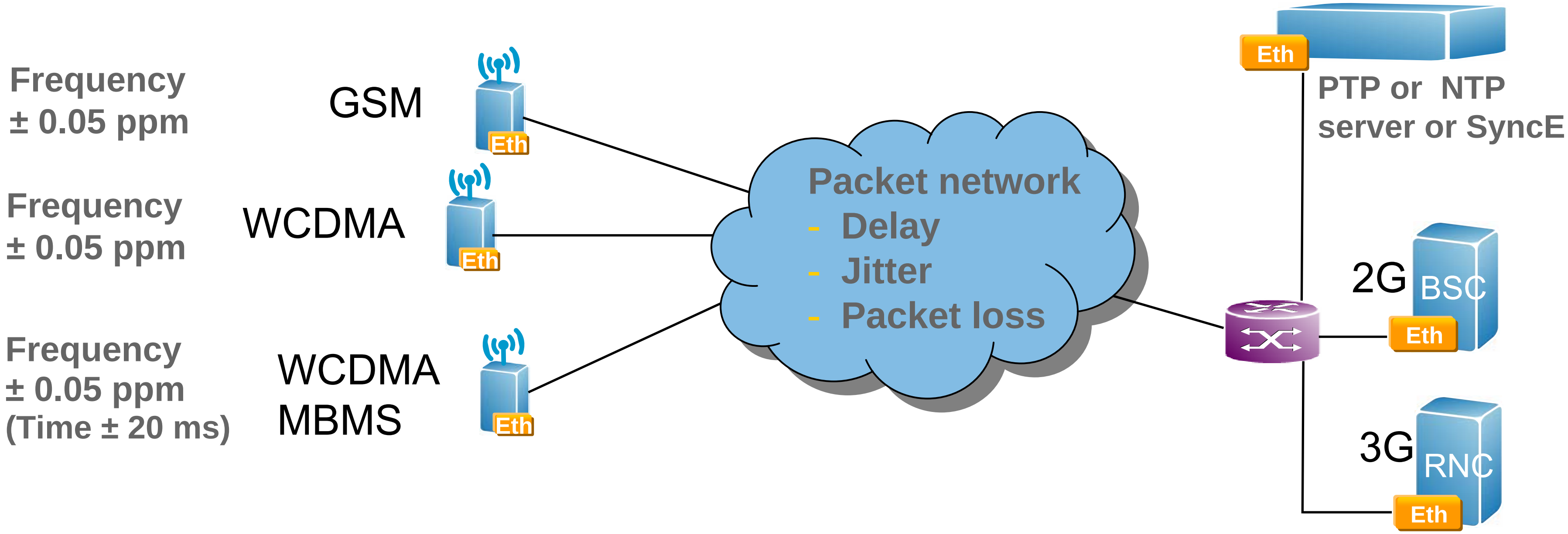
Introduction

- Migration of mobile networks into packet transport requires a new solution for distributing frequency synchronization.
- Some mobile systems require also time synchronization. Currently they are synchronized via GPS. The trend towards smaller base stations increase the relative cost of GPS receiver, GPS antenna installation, and antenna site rental.
- Majority of radio technologies introduced during recent years are also time synchronization dependent.
- Thus, a new synchronization method for packet networks is desired, which
  - Can provide frequency synchronization over current packet networks.
  - Holds a promise for microsecond level time synchronization over the network within a few years.
- IEEE 1588 precision time protocol, PTP, is a promising candidate to satisfy the requirements above. Migration of PTP into mobile networks is discussed in this presentation.

Some Mobile Technologies

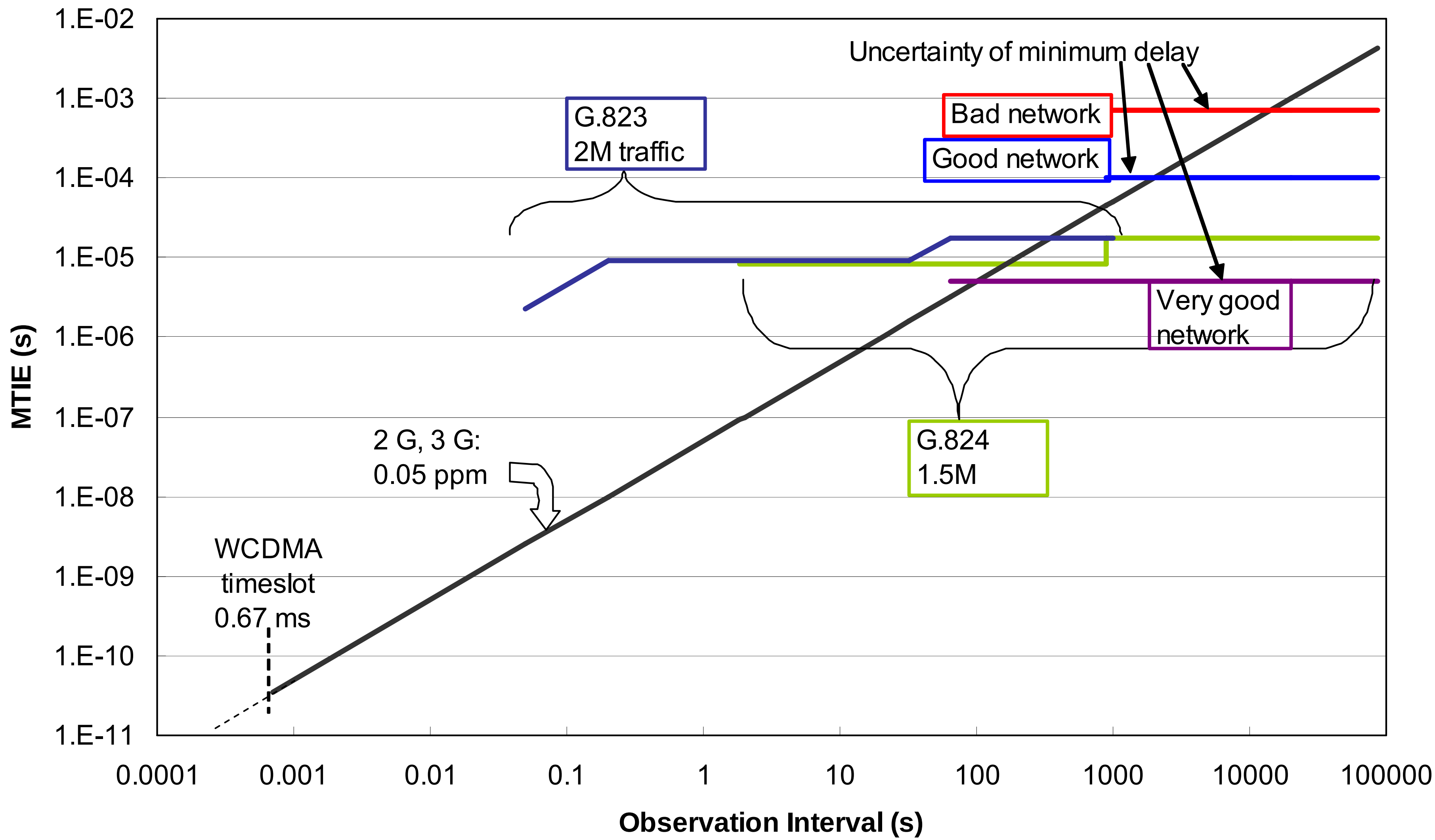
GSM	Global System for Mobile Communications
CDMA	Code Division Multiple Access
WCDMA	Wide-band CDMA
3G LTE	3G Long Term Evolution
Mobile WiMAX	Mobile Wireless MAN, IEEE 802.16e
DVB-H	Digital Video Broadcasting Handheld

Frequency Synchronization Requirements and Solutions



MBMS	Multimedia broadcast multicast service
NTP	Network time protocol
SyncE	Synchronous Ethernet
BSC	Base station controller
RNC	Radio network controller

MTIE Relations in a Time Protocol Agnostic Network



MTIE = Maximum time interval error

Frequency Synchronization in Packet Networks - Comparison between IEEE 1588, NTP, and SyncE

	IEEE 1588 v.2	NTP	SyncE
Cost	Medium	Medium	Low
Possible over protocol agnostic network	Yes	Yes	No
Multiple timing domains over single trunk	Yes	Yes	No
Downlink-only mode available for saving time server load in unicast	Yes	No	Multiple slaves do not increase load of server
Slave cold-start lock speed in Agnostic/Compliant netw.	Slow/Medium	Slow/Medium	Not possible/Fast
Matureness	Standard products entering market	Mature	Pre-standard products on the market

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Implementing IEEE 1588, PTP, in Legacy Packet Networks for WCDMA and WCDMA with MBMS

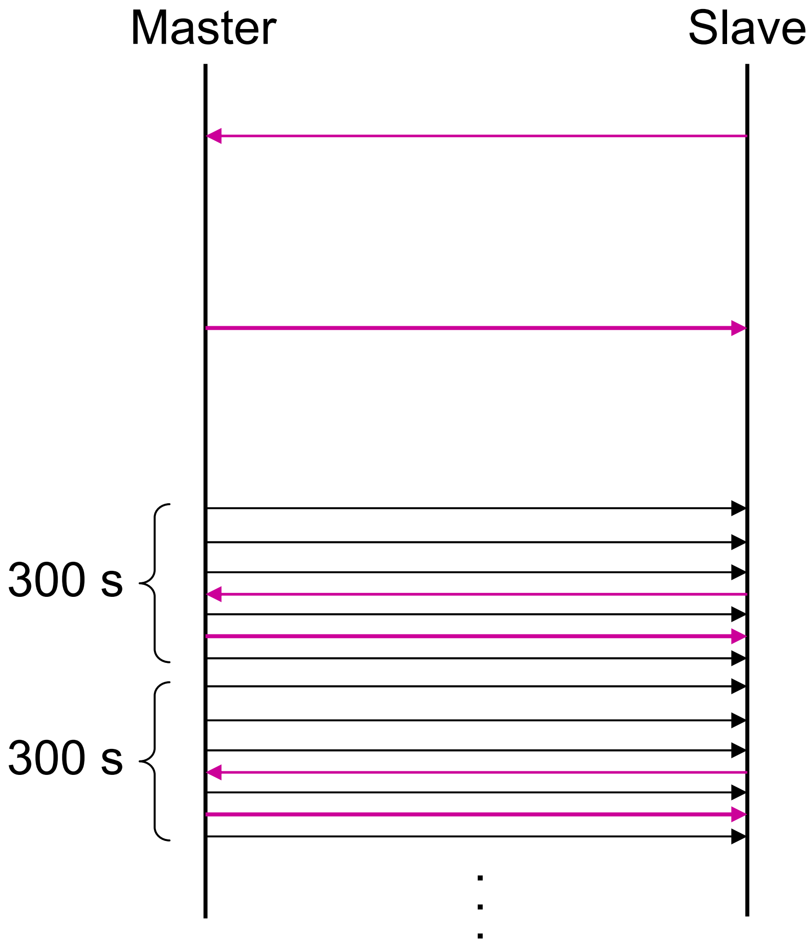
- Leased lines support typically only unicast.
- Packet networks will be IEEE 1588 agnostic at least for some years.
- Annex A.9 (informative) of IEEE 1588 v.2 describes how PTP can be operated in legacy packet networks
  - The annex proposes to utilize Clauses 16.1 and 17.5
  - Clause 16.1 defines TLVs in signaling messages for requesting unicast announce, sync and delay request messages.
  - Clause 17.5 defines a unicast master table and management message TLV for managing the table.
- **WCDMA FDD** requires frequency synchronization only → delay request not mandatory for obtaining synchronization
- **WCDMA with MBMS** requires additionally ± 20 ms time accuracy → can be achieved reliably in planned networks by using sync messages and delay requests.

TLV = Type-length-value

FDD = Frequency division duplex

Example of Master Slave Communication, Single Master, Frequency Synchronization only

All slaves are preconfigured with the address of the master.



Signaling message
REQUEST_UNICAST_TRANSMISSION TLV
messageType: Sync, logInterMessagePeriod: 1/8 s,
durationField: 300 s

GRANT_UNICAST_TRANSMISSION TLV
messageType: Sync, logInterMessagePeriod: 1/8 s,
durationField: 300 s, R flag (Renewal Invited): TRUE

Sync messages (8 packets per second for 300 s)

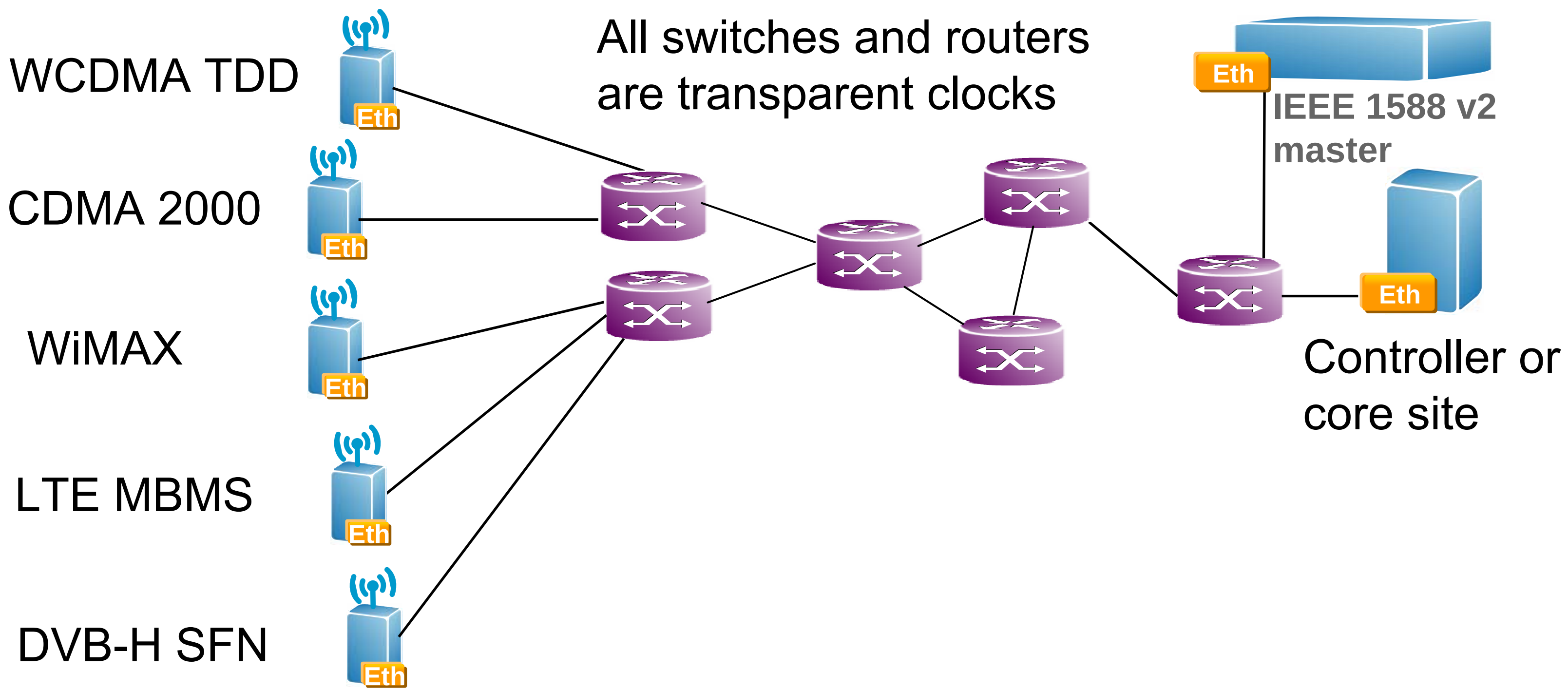
Request
Grant

Sync messages

Request
Grant

Systems, which Require Time Synchronization

Some old systems require microsecond level timing accuracy. In addition, all new OFDM (orthogonal frequency division multiplexing) based systems have either TDD (time division duplex) mode or SFN (single-frequency network) mode, which require microsecond level timing accuracy.



Time Accuracy Requirements

System	TX timing accuracy
Mobile WiMAX TDD mode, BW: 10 MHz, FFT: 1024, Cyclic pref. r. 1/8	± 0.7 µs* IEEE 802.16e ± 0.5 µs* Mobile WiMAX System profile v0.1.2 (if micro sleep allowed during handover)
WCDMA TDD	± 1.25 µs*
LTE MBMS	± 5 µs (estimate based on simulations)
CDMA 2000	± 3 µs, (± 10 µs worst case)

* Some standards define max BTS-BTS time difference, e.g. 1.4 µs for WiMAX, and not a difference against a common reference as here.

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DVB (-T / -H) Single-Frequency Network (SFN) Accuracy Requirements

Values for frequency and time accuracies are given in ETSI TR 101 190, “Implementation guidelines for DVB terrestrial services; Transmission aspects”

	Proposed rule	Numerical values
Mode		BW: 8MHz, FFT 8k, GI: 224 µs
Frequency	$f_k \pm (\Delta f/1\ 000)$ *	± 1 Hz* → ± 1.5 ppb @ 706 MHz
Time	No rule given in guidelines	± 5 µs**

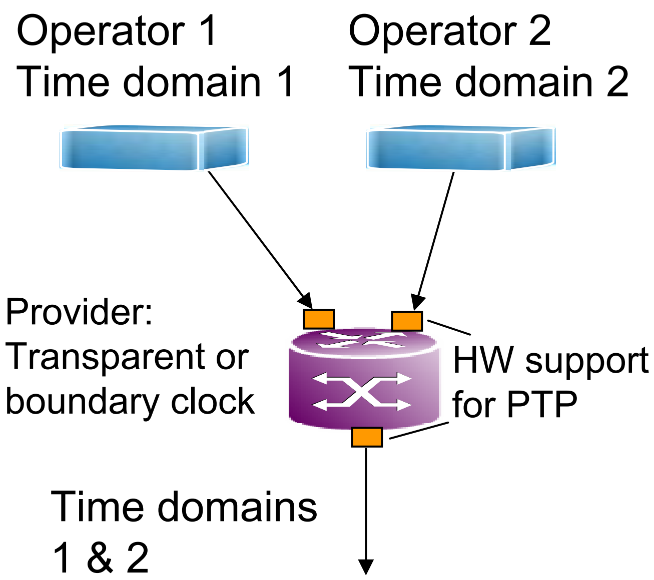
* “To be confirmed by adequate field test.” Doppler limit in a field test, see TR 102 401, was 110 km/h at 706 MHz, which is ± 100 ppb. By giving away 5 % to TX frequency error, ± 5 ppb could be allowed for RF frequency error.

** “…tolerances of ± 5 µs should not cause performance degradation.” 1/20 of guard interval between BTSs would be ± 7.5 µs.

Time synchronization in Packet Networks - Comparison between IEEE 1588, NTP, and SyncE

	IEEE 1588 v.2	NTP	SyncE
Cost	Medium	Medium	Medium
Possible over protocol agnostic network	No	No	No
Time synchronization chain supported in std.	Yes, boundary/ transparent clock	Allows, can be configured as boundary-clock type chain	No, method of realization proposed.
Multiple timing domains over single link	Yes	Not in std	No
Matureness – availability of switches and routers	Version 1 switches on market. Version 2 prototypes exist.	No products with adequate accuracy	No products

Implementing IEEE 1588 for Time Synchronization



Multicast mode, boundary clocks

- Provider nodes have to lock into all timing domains that are supported.
- Very little timing traffic
- Original best master clock (BMC) algorithm could be used.

Multicast mode, transparent clocks

- If end-to-end mechanism is used, the provider nodes do not need to be synchronized (100-ppm oscillator, 200 μs transit time → 20 ns error per node). Peer-to-peer ok if short distances guaranteed.
- Provider nodes need to process ca. one packet per second per slave, if low-quality slave oscillators are used. Otherwise much less is adequate.
- Original BMC algorithm could be used.

Unicast mode, transparent clocks

- Solution when leased line service does not support multicast.
- Timing performance as in the previous case.
- Interfaces of time servers and provider nodes near the time servers experience higher timing packet flows.
- Original BMC algorithm has not been designed for unicast.

IEEE 1588 hardware support for VLAN, Q-in-Q, MPLS, etc. frames is required in all cases if PTP is encapsulated in these frames.

Conclusions

- The current frequency synchronization requirements of mobile networks can be satisfied over legacy packet networks using IEEE 1588 v. 2 or NTP.
- Mass deployment of new systems requiring time synchronization will start in a few years. On the other hand, the relative cost of GPS solution is increasing as base stations become smaller.
- Currently IEEE 1588 is the only standard that is ready for carrying microsecond level time synchronization over large networks. Thus, it is an attractive choice for solving the acute frequency synchronization need - and for providing accurate time synchronization over network if switch and router vendors start implementing the standard.