

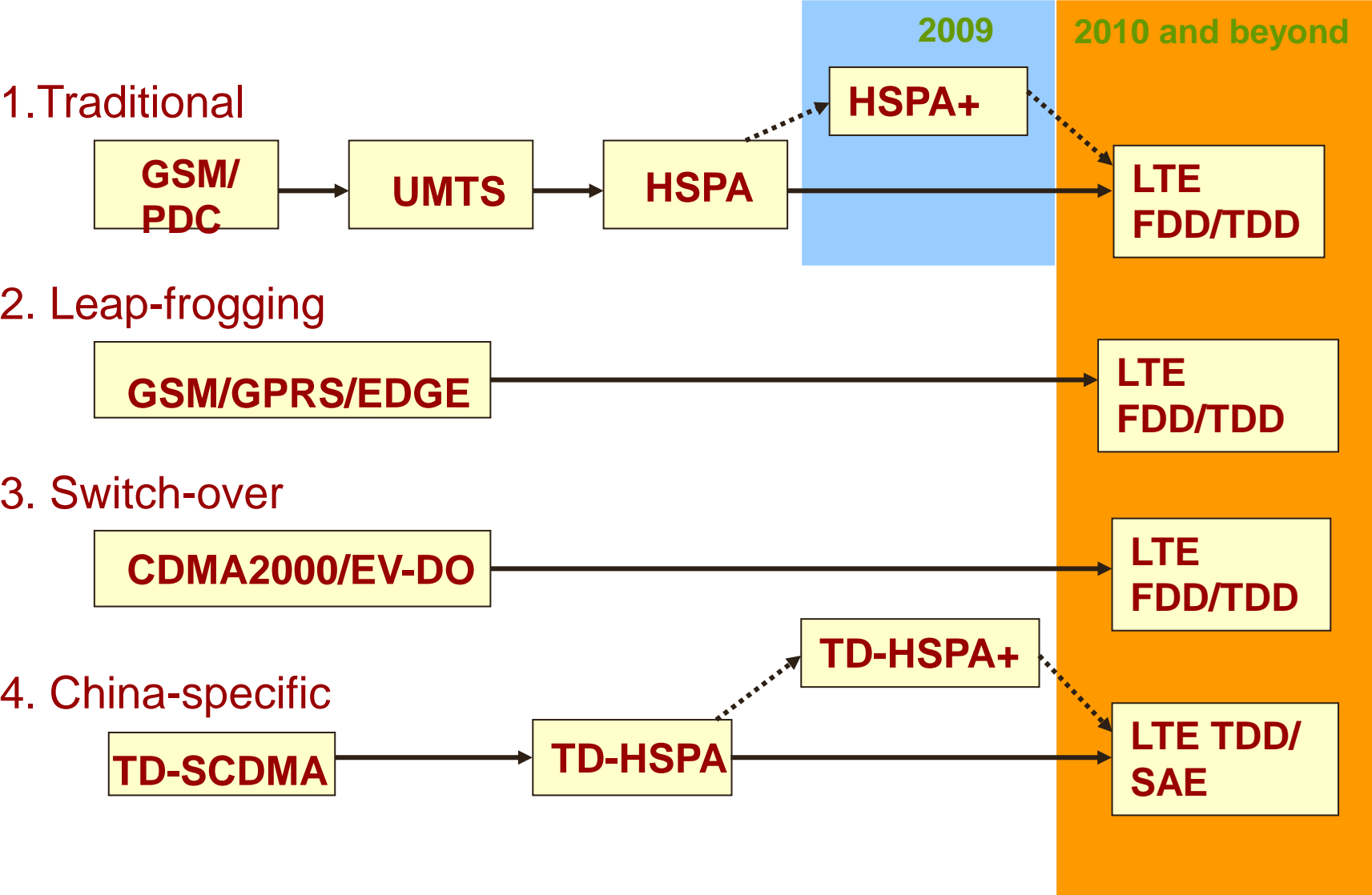
Time Synchronization for Digital Subscriber Lines

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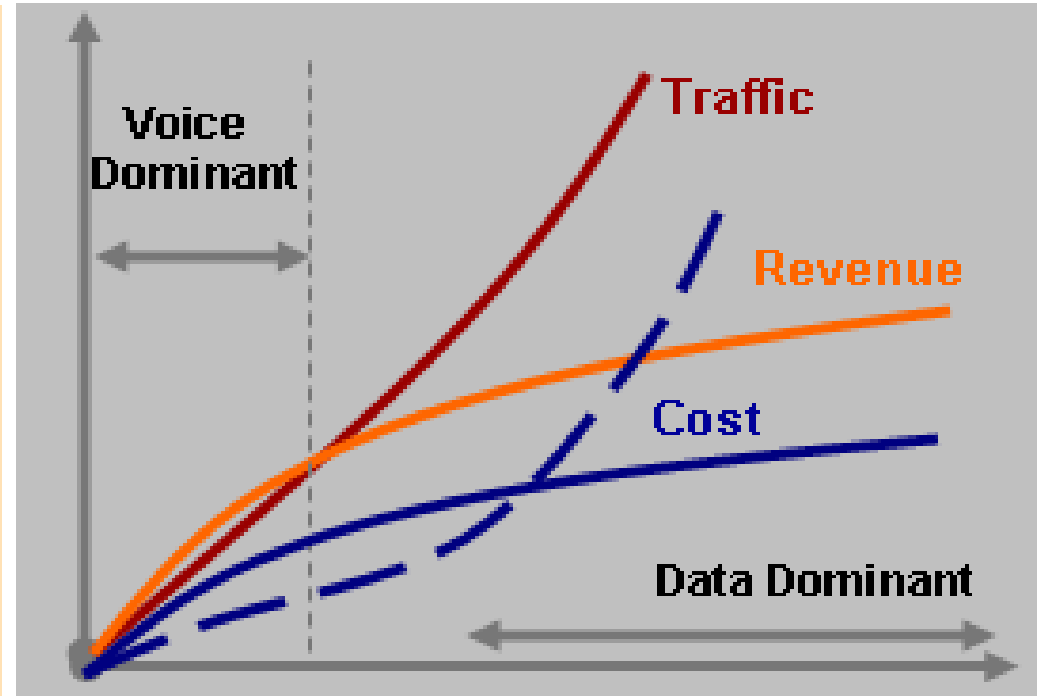
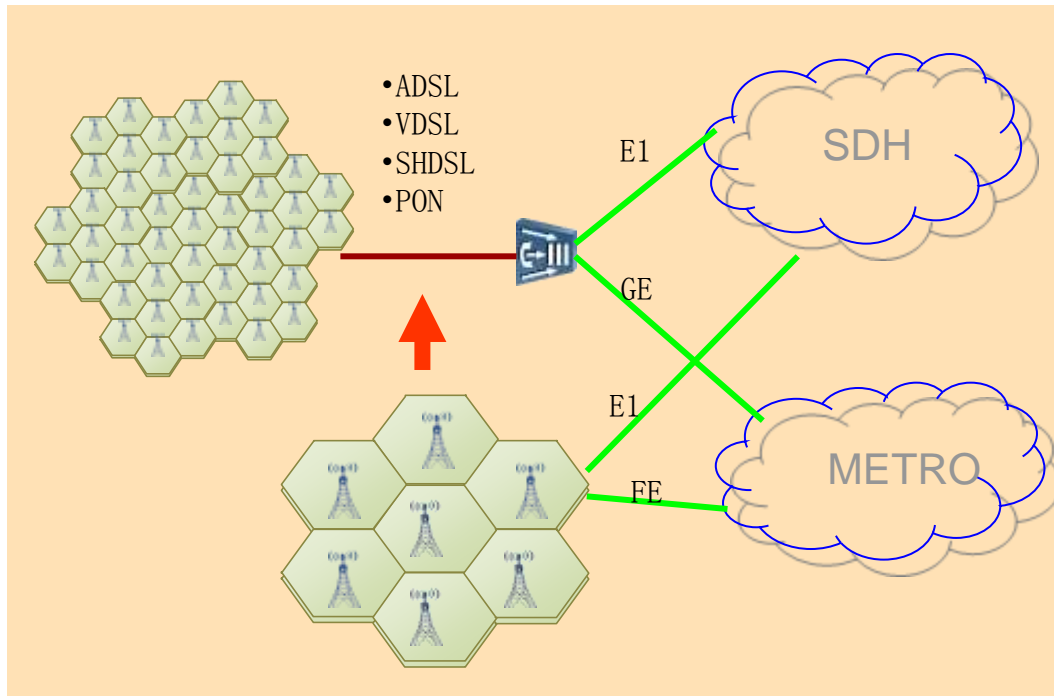


Mobile Broadband Evolving Towards LTE



■ LTE is the trend for mobile broadband

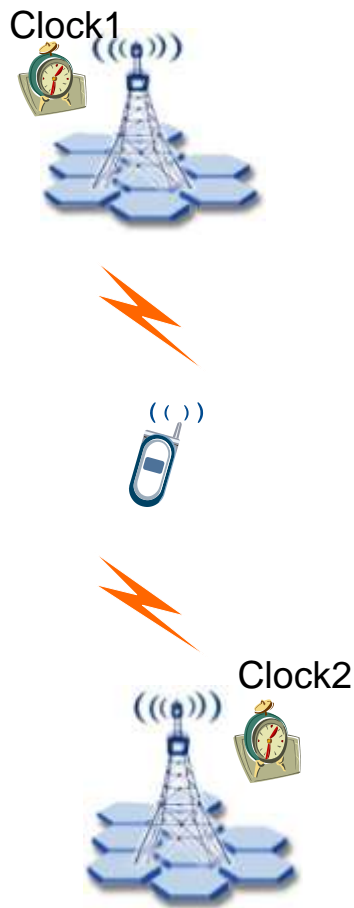
Mobile Backhaul Migration



- **LTE CAPEX/OPEX soars due to mass number of femto cells and complicated wireless coverage scenarios.**
- **To maintain profitability in Mobile Broadband era, cost must be kept in line with revenue.**
- **Cost-effective backhaul is one of the key requirements.**

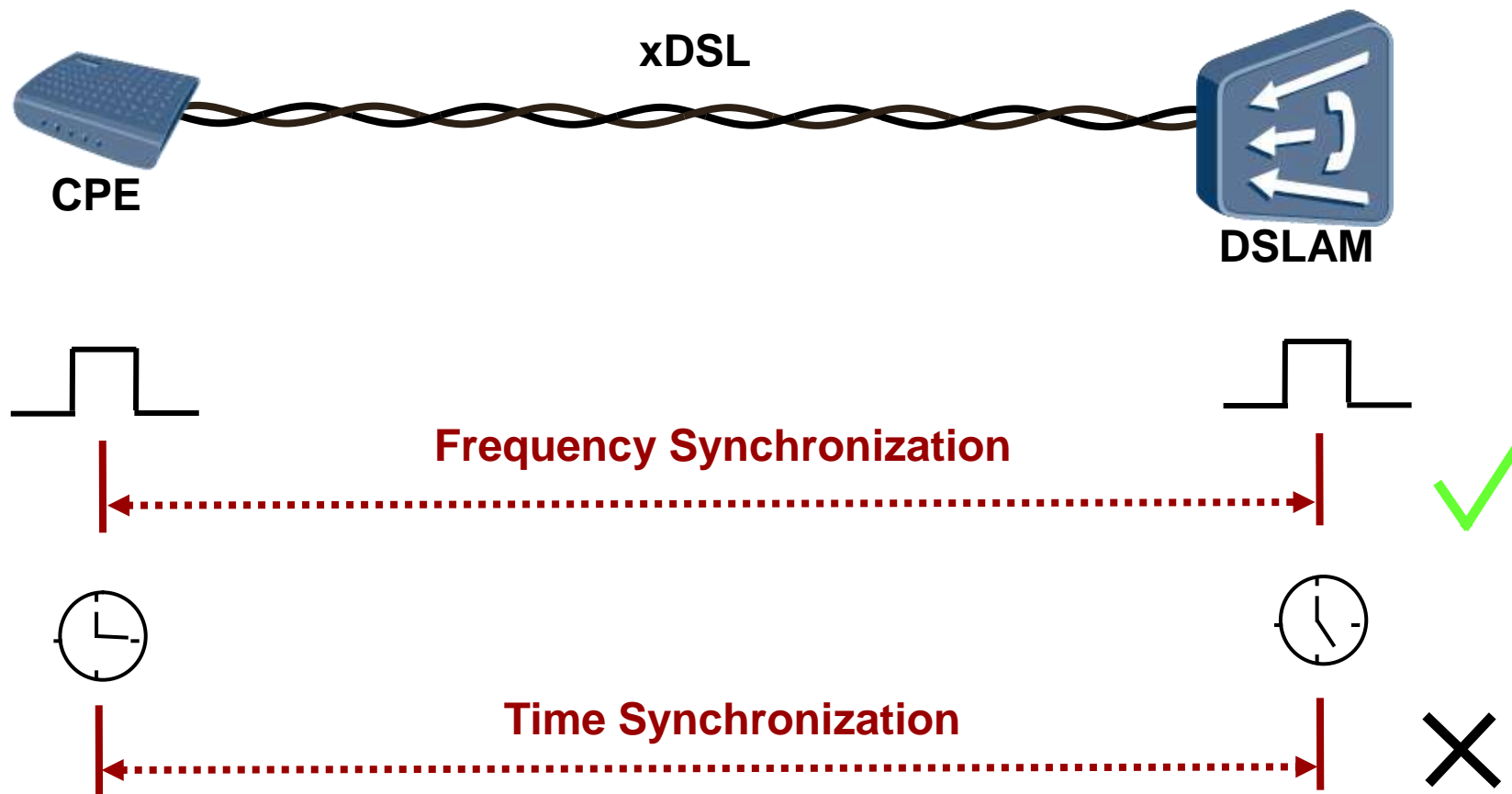
Precision Requirements for Synchronization

To be an appealing alternative for mobile backhaul, DSL must support precise frequency/time/phase synchronization.



Mobile Network	Frequency Sync	Time/Phase Sync
GSM	0.05 ppm	N/A
WCDMA	0.05 ppm	N/A
TD-SCDMA	0.05 ppm	3 μ s
CDMA2000	0.05 ppm	3 μ s
WiMax FDD	0.05 ppm	N/A
WiMax TDD	0.05 ppm	1 μ s
FDD-LTE	0.05 ppm	4 μ s
TDD-LTE	0.05 ppm	0.4 μ s, 0.1 μ s (Location dependent)

Synchronization in Current DSL Systems



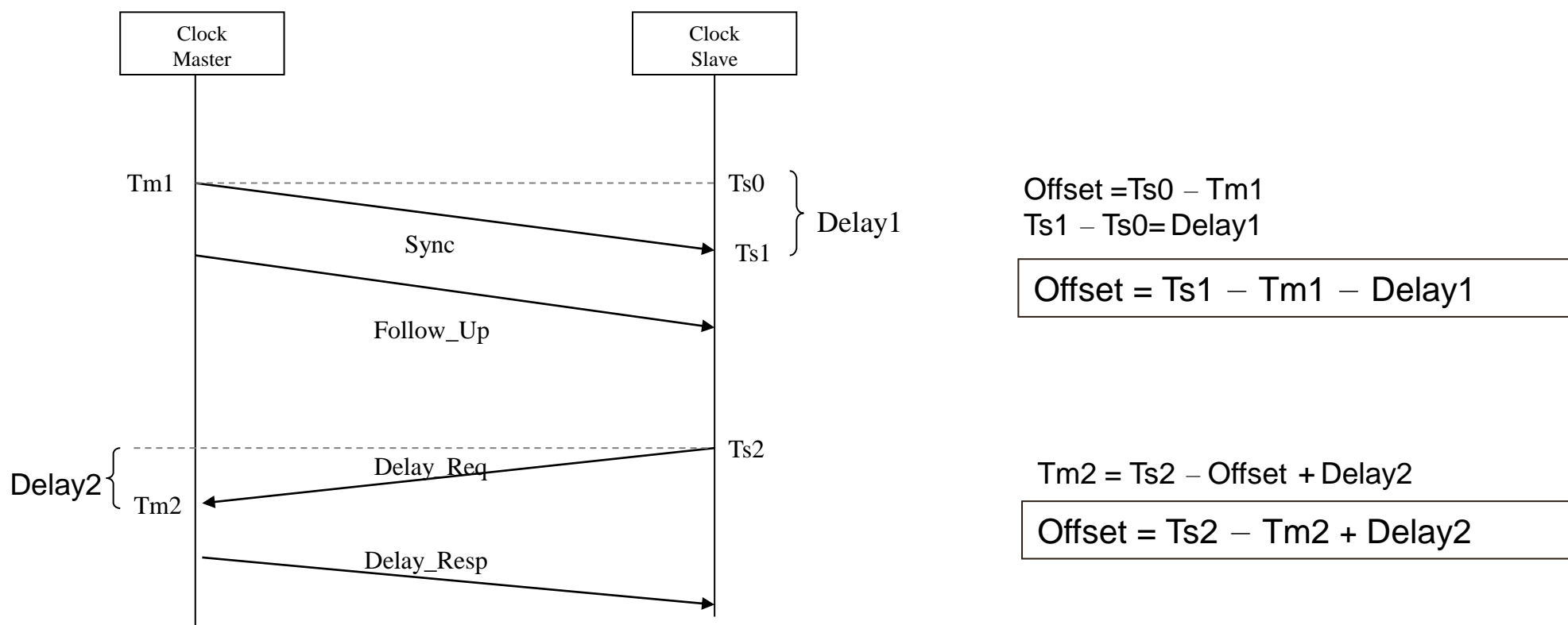
Current DSL systems do not support time/phase synchronization

Network Timing Reference (NTR)

- **NTR: Phase error between network clock and local clock is differentially encoded and transmitted from the CO to the CPE via an embedded channel to recovery clock.**
- **It is specified in ITU-T Recommendations for xDSL as a mechanism for frequency synchronization.**
- **However, it does not support time/phase synchronization.**

IEEE1588v2 – Precision Time Protocol (I)

Two-way mechanism to calculate the time offset between master clock and slave clock.



IEEE 1588v2

IEEE1588v2 - Precision Time Protocol (II)

■ Necessary condition for solving the simultaneous equations:

The link's dual directional delays must be identical:

$$\text{Delay1} = \text{Delay2}$$

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$$\text{Offset} = \text{Ts1} - \text{Tm1} - \text{Delay1}$$

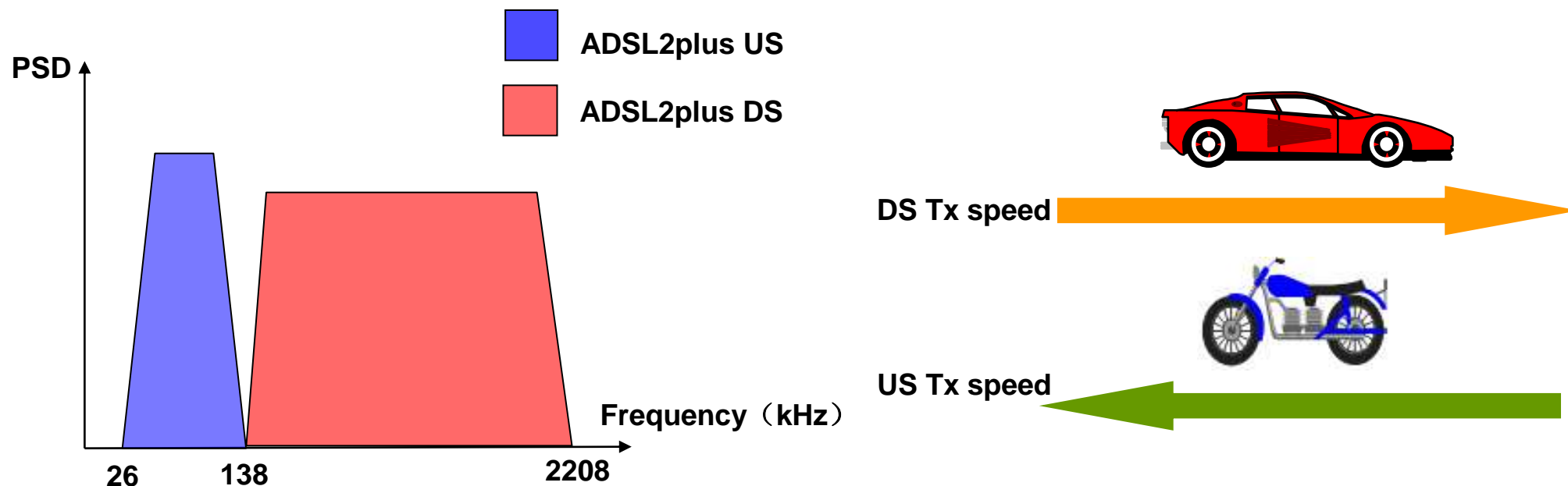
$$\text{Offset} = \text{Ts2} - \text{Tm2} + \text{Delay2}$$

$$2 \times \text{Offset} = (\text{Ts2} + \text{Ts1}) - (\text{Tm2} + \text{Tm1})$$

$$2 \times \text{Delay} = (\text{Ts1} - \text{Ts2}) - (\text{Tm1} - \text{Tm2})$$

Can we apply IEEE 1588v2 PTP to DSL?

1st Technical Challenge: Asymmetrical Delays

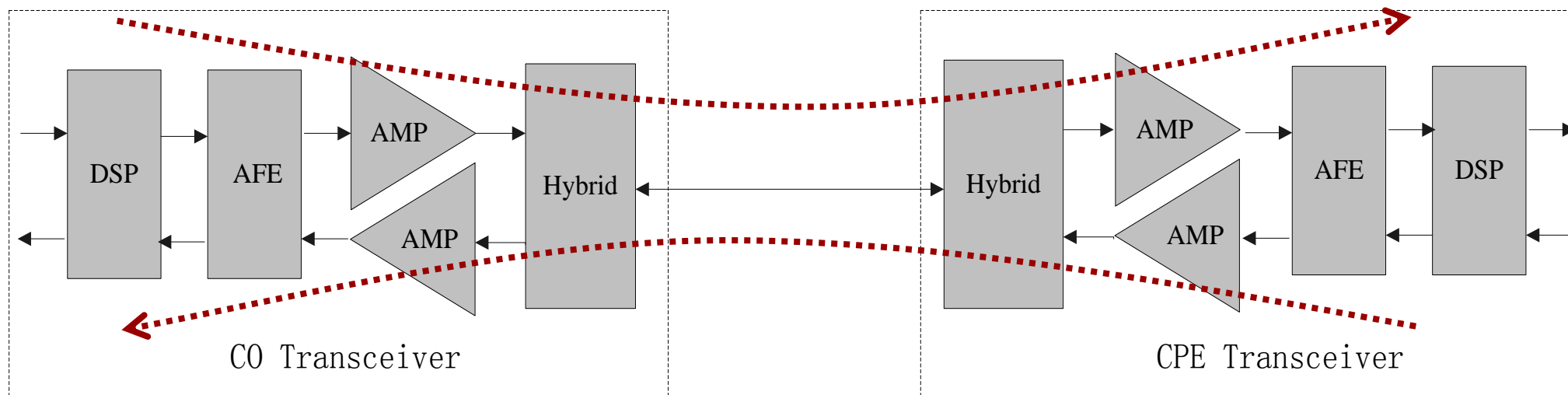


- DSL systems use different frequency bands in upstream (US) and downstream (DS) directions.
- DS and US end-to-end signal transmission delays of a DSL link are different.

2nd Technical Challenge: Delay Jitters

- **It is observed that a DSL link contains the following sources for generating packet jitters in the order of 250 microseconds:**
 - **FEC encoder/decoder**
 - **mapping onto DMT symbols**
 - **symbol transmission/reception**
 - **insertion of Sync symbols**
 - **transmitting user data to higher layer**

Technical Challenges Inherited to DSL



- **DSL transceiver consists of digital part and analog part, which result in asymmetrical DS & US end-to-end delays and delay jitters.**
- **IEEE 1588v2 P2P method cannot be directly applied to a DSL link.**

Huawei's Solution

- **Key observation:**

For typical xDSL implementations over various loops, the difference between US and DS propagation delays measured at the U reference points (i.e., on the copper line) in certain frequency bands is in the order of tens of nanoseconds

- **Key idea:**

Apply IEEE 1588v2 PTP at the U reference points to estimate the time offset between the clocks on the two sides

- **Advantages: overcomes the two challenging technical issues related to xDSL**

1. asymmetry between the downstream and upstream end-to-end propagation delays
2. packet jitters inside a DSL link

Two-Way PTP Methodology (I)

- At the VTU-O, a time stamp is taken on the downstream reference sample at time instant t_1 when this reference sample, being transmitted to the VTU-R, arrives at the U-C reference point
- At the VTU-R, a time stamp is taken on the same downstream reference sample at time instant t_2 when this reference sample arrives at the U-R reference point
- The transmission delay from the U-O reference point to the U-R reference point is denoted as $delay_{DS}$
- The time offset between the clocks at the VTU-O and the VTU-R is denoted by $offset$

$$t_1 + delay_{DS} + offset = t_2$$

Two-Way PTP Methodology (II)

- At the VTU-R, a time stamp is taken on the upstream reference sample at time instant t_3 when this reference sample, being transmitted to the VTU-O, arrives at the U-R reference point
- At the VTU-O, a time stamp is taken on the same upstream reference sample at time instant t_4 when this reference sample arrives at the U-O reference point
- The transmission delay from the U-R reference point to the U-O reference point is denoted as $delay_{US}$

$$t_3 + delay_{US} - offset = t_4$$

Two-Way PTP Methodology (III)

- The time stamps t_1 and t_4 are transmitted from the VTU-O to the VTU-R with eoc messages
- After receiving both time stamps t_1 and t_4 , based on the fact that the transmission delays (i.e., $delay_{DS}$ and $delay_{US}$) are sufficiently symmetric, the VTU-R estimates the time offset between the real-time clocks at the VTU-O and the VTU-R as

$$offset_{est} = \frac{t_2 - t_1 + t_3 - t_4}{2}$$

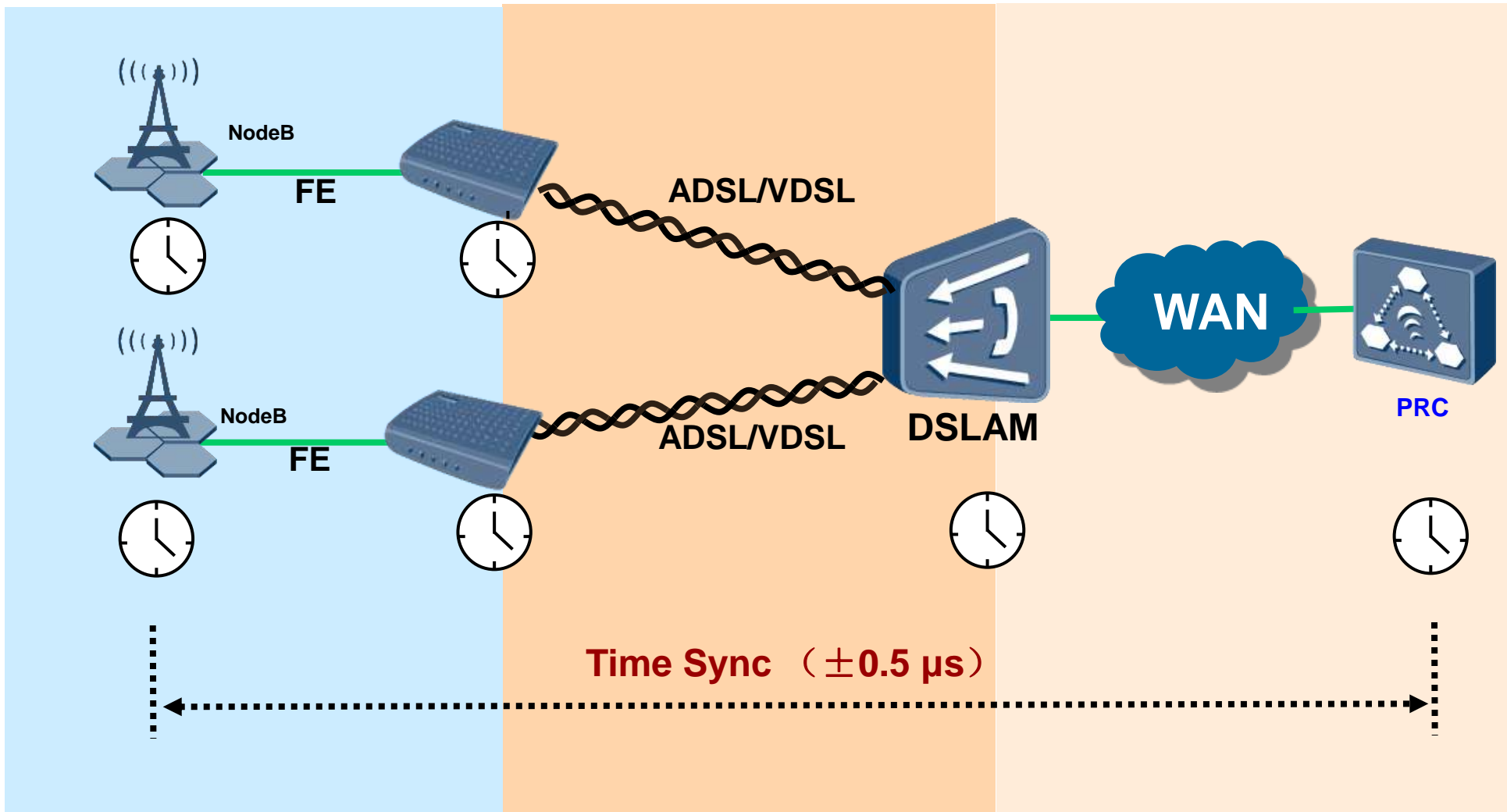
Time Stamping

- The location where the time stamps are taken and received in the DSL functional model is a critical issue
- Using the set of time instants $\{t_1, t_2, t_3, t_4\}$ ensures that our proposed method meets the key assumption in the two-way IEEE 1588v2 mechanism: symmetric propagation delays
- In practice, it is difficult to obtain the set of time instants $\{t_1, t_2, t_3, t_4\}$ with analog circuits at the U reference points
- Instead of taking a time stamp t_1 when a reference sample arrives at the U-O reference point, it is easier to implement by taking a time stamp t_1' when the same reference sample arrives at the output of the IDFT of the VTU-O. The time stamp t_1 is then obtained by adjusting the time stamp t_1'
- The same way applied to $\{t_2, t_3, t_4\}$

Standardization and Prototype

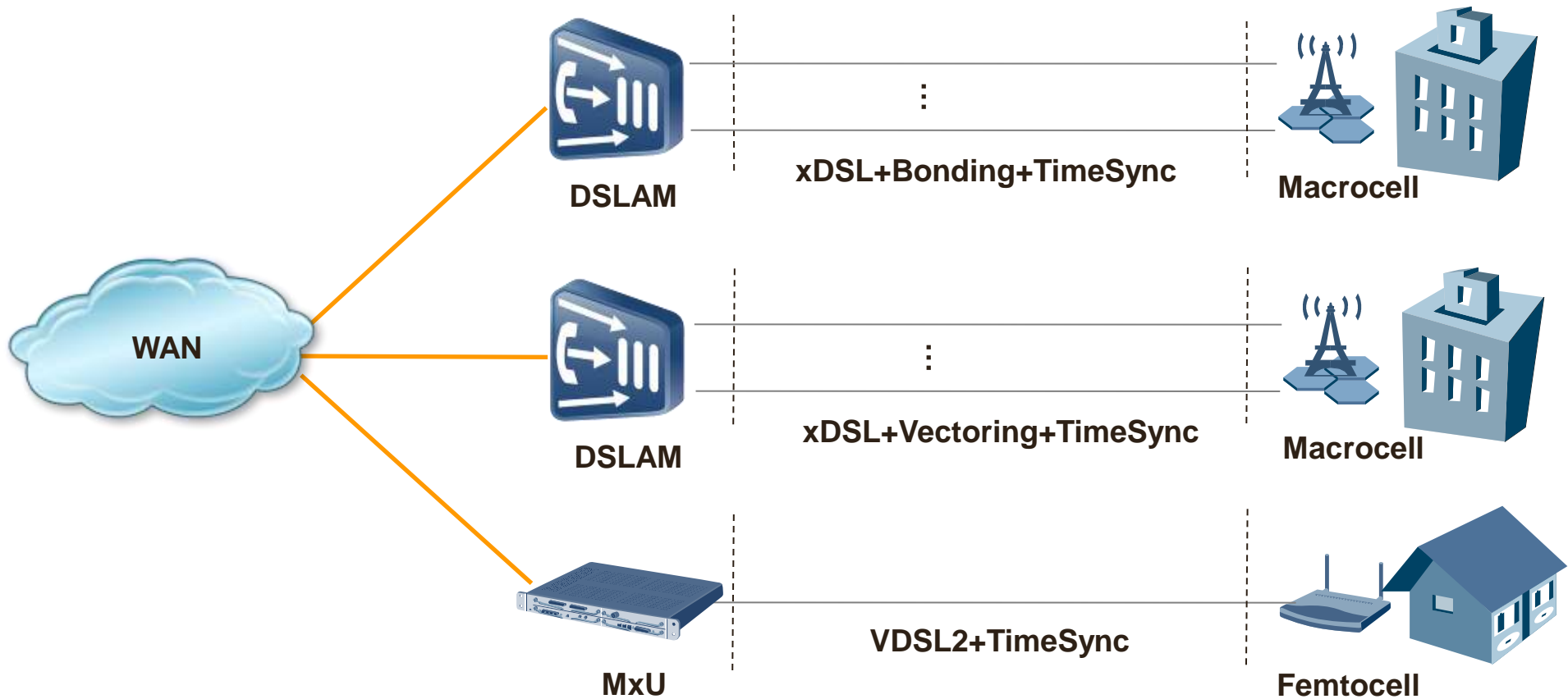
- The feature of time synchronization in xDSL was first requested by China Unicom and Ministry of Industry and Information Technology of China in 2009
- Huawei demonstrated the first DSL prototype with precise time synchronization function in March, 2010
- Huawei first proposed its solution to ITU-T SG15 Q4 in March, 2010
- A working text based on this solution was accepted in August, 2010
- The standardization of this feature is expected to be finished by February, 2011

Time Sync in xDSL for Mobile Backhaul



Precision requirement for time sync can be met with Huawei's solution

Application Scenarios



FTTx+xDSL can be a high-performance and cost-effective solution for mobile backhaul

Benefits of xDSL for Mobile Backhaul

- Ubiquitous availability
- Reuse of copper resources
- Simple installation and easy maintenance
- Reduction in OPEX and CAPEX compared with other alternatives
- Bottom line: DSL equipped with time synchronization is an appealing alternative for mobile backhaul.

Thank You!

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