Synchronization over Packet Switched Networks PLL Concepts

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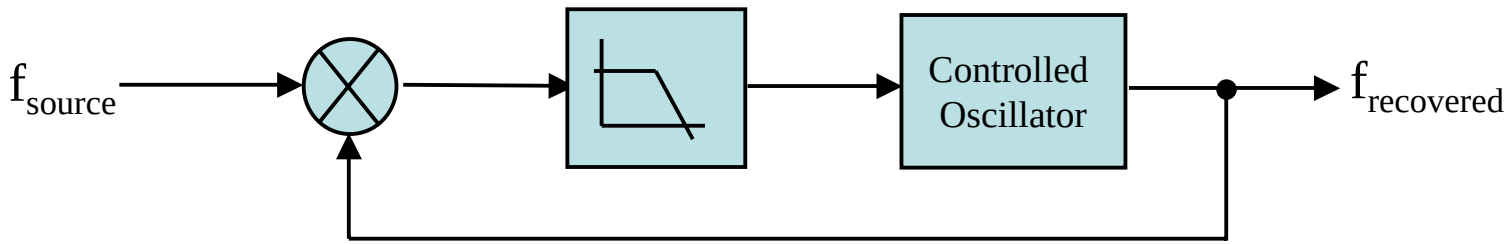
Agenda

- **Traditional phase locked loop (PLL) architecture and synchronization over Packet Switched Network (PSN)**
- **One-way communication and phase lock**
- **Two-way communication and phase lock with latency correction**
- **Applications**
  - **Phase/frequency lock**
  - **Phase lock with latency correction**

    Can synchronization over PSN be employed when tight phase alignment is expected?

Traditional Phase Locked Loop



- **Locked:**

  $\Delta\theta$ = constant (static phase error)

  => Δf = 0 and $f_{source} = f_{recovered}$

- **PLL phase detector manages desired pull-in range and expected static phase error**
- **PLL bandwidth manages the frequency at which θ_s can vary and still be followed closely by θ_r, or rate at which f_{source} can vary and still be followed by $f_{recovered}$**

Traditional Phase Locked Loop – cont'd

- **Analog and digital PLL implementations for a wide range of applications**
  - **Rate convert, frequency multiply, jitter and/or wander filter, frequency modulate or to provide protection against source clock phase and frequency disruptions**
- **Example 1 – Timing telecommunication network elements**
  - **Requires clock reliability and frequency alignment to manage physical layer slip buffers, filter disruptions, jitter and wander**
    - **Narrow bandwidth PLL is desired**
    - **Eliminating static phase error is of no value**
- **Example 2 – Timing industrial automation equipment**
  - **Requires aligning time domains for all robotic machines (Example: align the start time when 2 robots share the load of 1000 Kg box)**
    - **Eliminating static phase error is a must**
    - **Employing short time constant (wide bandwidth PLL) may be desirable**

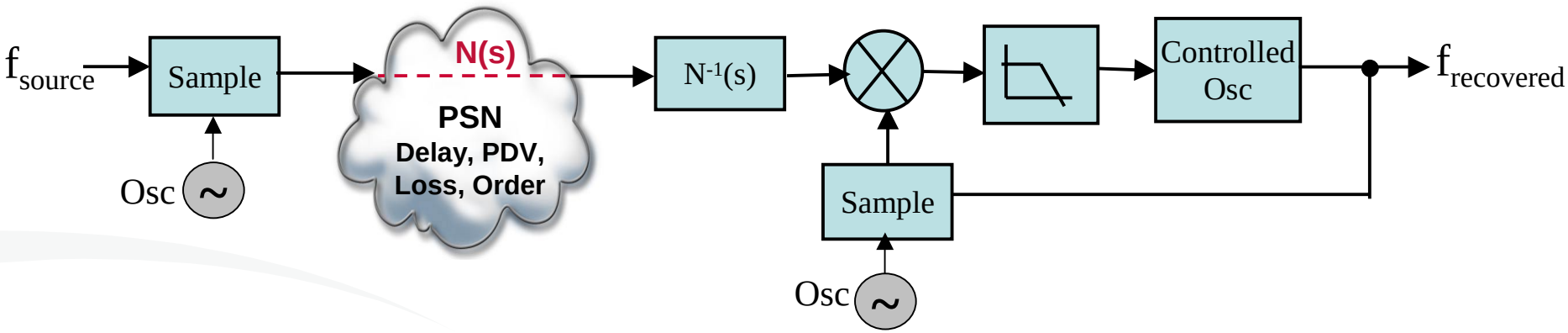
Synchronization over Packet Switched Network – Concept

- **Based on a server–client configuration**
- **Server:**
  - **Provides solution to send source clock phase/frequency information**
    - **VoIP and CESoP – send packet sequence number at data sampling rate**
    - **RTP, NTP and IEEE1588™ – send reference clock time-stamping information at a pre-defined rate**
- **Client**
  - **Processing and intelligent filtering of received timing information**
  - **Synthesize the desired output frequency**

Techniques of “Adaptive” Clock Recovery for Synchronization over PSN

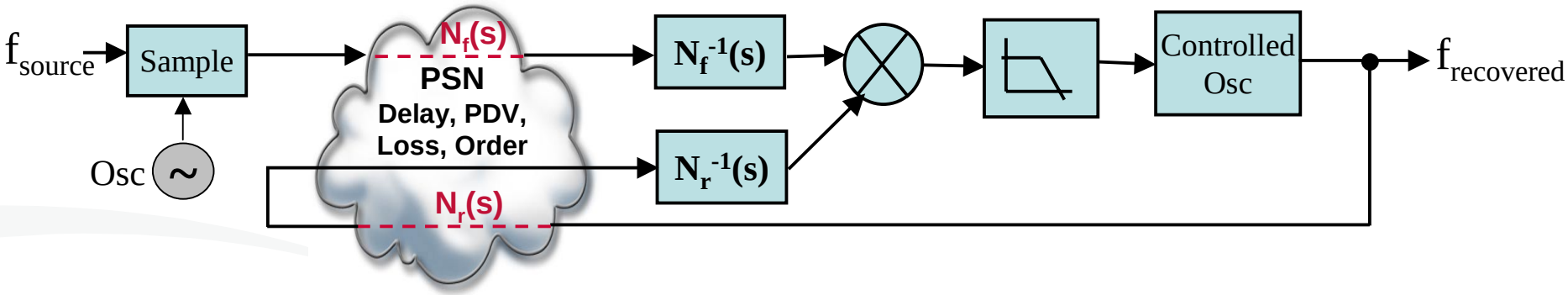
- **When the synchronization information is only sent from the server to client(s), this presentation will refer to the technique as “one-way communication sync. information”**
  - **This technique is employed VoIP, CESoP or RTP applications**
- **When the synchronization information could be sent from the server to the client(s) or from the client(s) to the server, this presentation will refer to the technique as “two-way communication sync. information”**
  - **This technique is employed NTP or IEEE1588 PTP applications**
- **It should be noted that NTP or IEEE1588 client could employ either one of the two techniques based on application requirements**

Synchronization over PSN Employing One-Way Communication Sync. Information



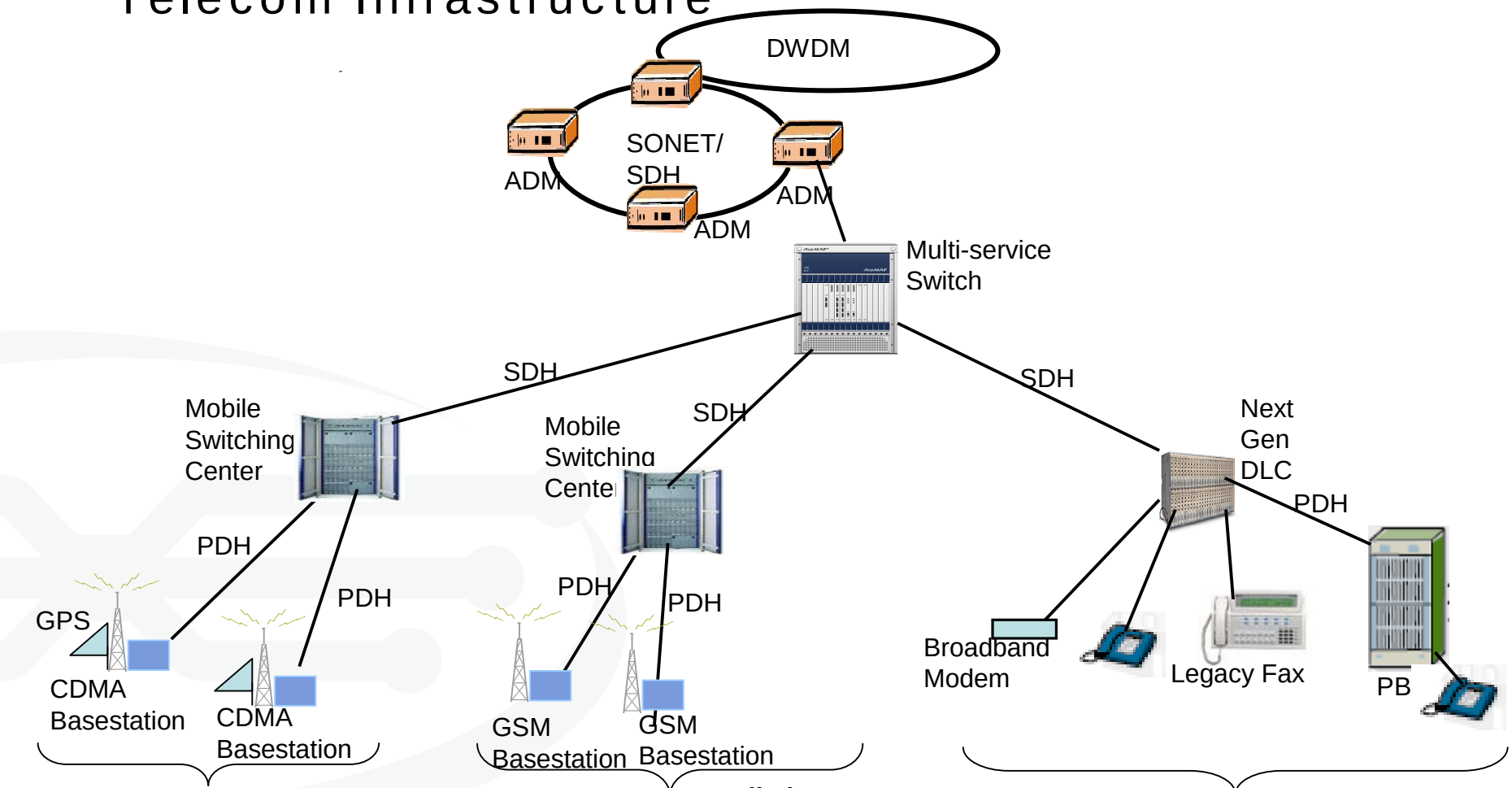
- **Technique achieves phase/frequency lock between source and recovered clocks**
- **Technique CAN'T perform latency correction**
- **Performance quality depends on:**
  - **Ability to filter network effects N(s)**
  - **Drift of the sampling oscillators and drift of the PLL's Controlled Oscillator (digital synthesis implementation at client could use same osc for both)**

Synchronization over PSN Employing Two-Way Communication Sync. Information

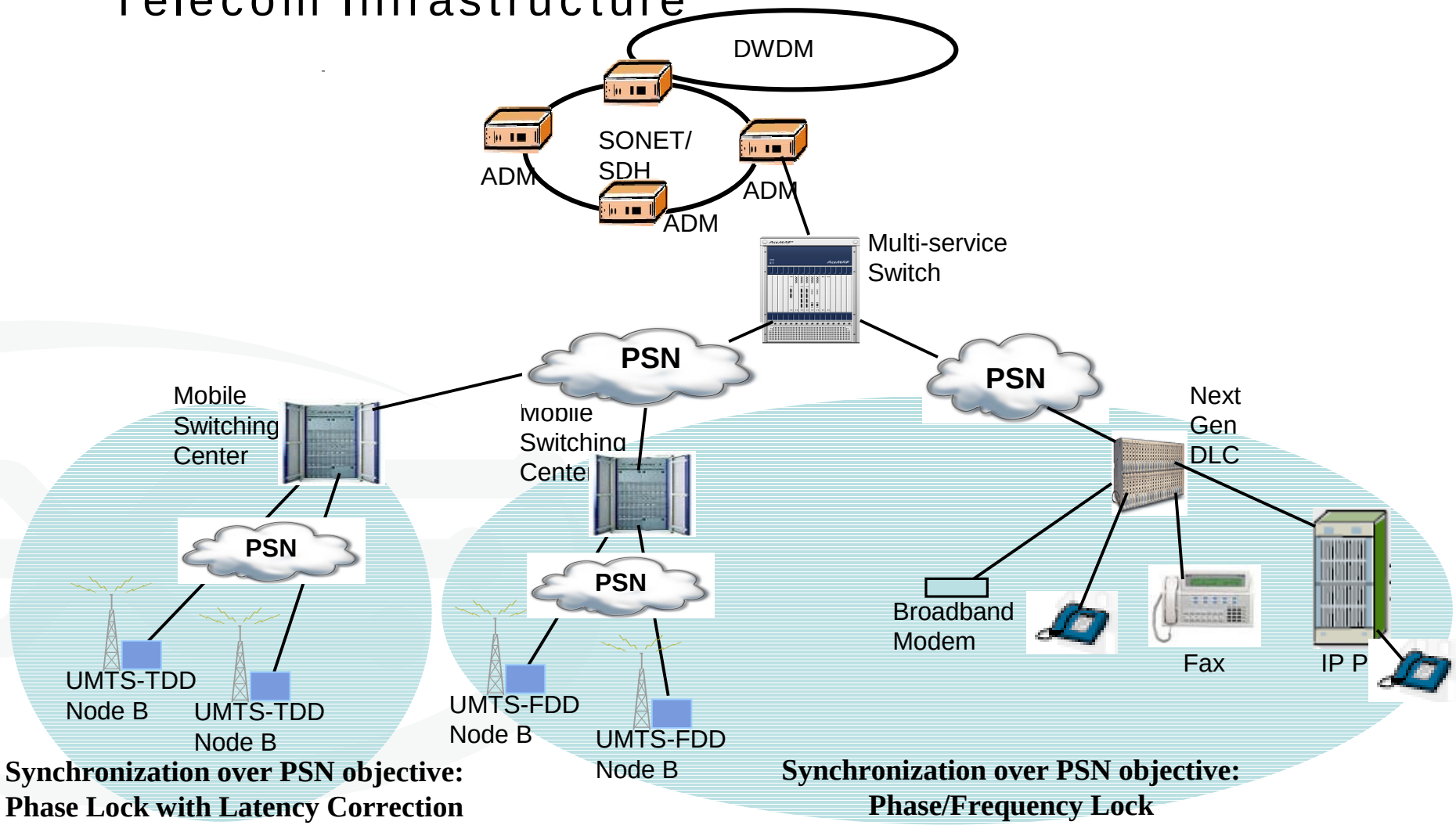


- **Technique achieves phase/frequency lock between source and recovered clocks**
- **Technique performs continuous latency correction**
- **Performance is dependent on:**
  - **The ability to filter network effect of the forward path $N_f(s)$ and the return path $N_r(s)$**
  - **Uplink and downlink path delay symmetry**
  - **Drift of the PLL's Controlled Oscillator**

Applications: Deployment in Wired and Wireless Telecom Infrastructure



Applications: Deployment in Wired and Wireless Telecom Infrastructure



Phase/Frequency Lock

- **Wired applications such as circuit emulation and transparent Modem/Fax-over-Packet expect phase/frequency lock with limited clock phase transients**
  - **PDH/SDH traceable PRS is the traditional synchronization technique**
- **Wireless applications such as UMTS-FDD and GSM expect only phase/frequency synchronization**
  - **Frequency accuracy better than 50 ppb is expected**
  - **PDH/SDH traceable PRS is the traditional synchronization technique**
- **CESoP, RTP, NTP and IEEE1588 protocols**
  - **one-way communication synchronization information could be employed to achieve desired level of accuracy**

Phase Lock with Latency Correction

- **Wireless applications such as UMTS-TDD and CDMA expect frequency synchronization and same time alignment between different nodes in the network**
  - **Less than 10 μsec of misalignment is allowed**
  - **Synchronization solution needs to provide controlled latency correction to achieve time division duplexing**
  - **GPS is the traditional technique in providing same time alignment**
- **NTP and IEEE1588 two-way communication synchronization could be employed to achieve desired level of accuracy**
- **Current protocols rely on symmetry of PSN. PSN with asymmetric path delay may suffer limited phase alignment accuracy. Solution:**
  - **Employ algorithms to cancel asymmetric delay effects**
  - **Deploy a hybrid GPS and synchronization over packet system**

    Use GPS to align UTC, and

    Use synchronization over packet as a standby clock that limits drift during GPS interruptions

Summary

- **Synchronization over PSN relies on the basic concepts of traditional PLLs**
- **The choice of the PLL parameters is based on the application requirements**
- **Both one-way communication synchronization over packet and two-way communication synchronization over packet represent a closed loop phase locked system**
- **One-way communication would achieve desired phase/frequency accuracy of wired applications (PDH/SDH) and for FDD-based wireless applications (UMTS-FDD and GSM)**
- **Two-way communication synchronization could be employed in TDD-based wireless applications (UMTS-TDD and CDMA)**

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