TDM circuit Emulation over IP

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Outline

What is TDM Circuit Emulation?

- Circuit Emulation is Technology that emulates either the characteristics of a circuit-switched network or of a TDM network, on segment of network based on packet- switched technology in order to carry CBR services (e.g. E1).

Figure: TDM circuit emulation over IP

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- For Enterprise to Protects investments in TDM based equipments.

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- It adds Uncontrollable delay as packetized and de-packetized at each TDMoIP hope.

Figure: Unstructured TDM(TDM= arbitrary bit-stream)

Structured TDMoIP

- TDM channels are individually transported across the IP network or grouped depending on their destination.

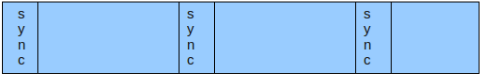

Figure: Framed(8000 frames per second)

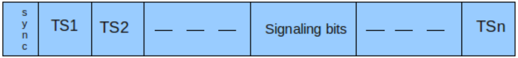

Figure: Channelized(single byte timeslot)

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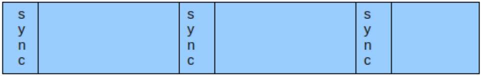

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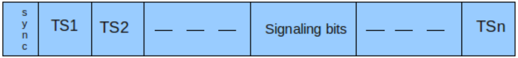

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Structured TDMoIP

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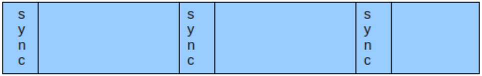

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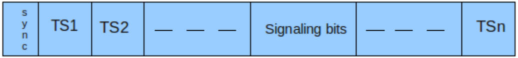

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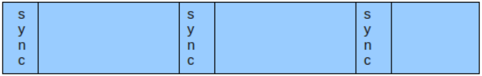
- Individually allow channel management based on priority.



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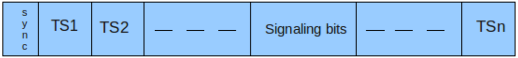

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Technology Challenges

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- Recover clock and Synchronization.
- Attenuate Packet delay variation.
- Compensate for Frame loss and out-of-sequence packets.

Bit about Traditional TDM

- How it works?
  - Timing is along with data.
  - Line coding is used.
  - Jitter and wander is filtered at each node.
  - Slave clocks uses PLL.
  - Hierarchical timing distribution.
    - Primary reference clock(PRC)
    - Synchronization Supply Unit(SSU)
    - SDH equipment clock(SEC)

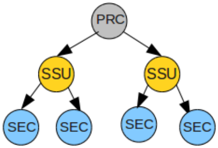

Figure: Hierarchical Timing Distribution

Attaining TDM Timing Goals for TDMoIP

- What are the problems?
  - No timing information is available.
  - No reference clock is available.
  - Delay degrades the voice quality.
  - PDV makes clock recovery difficult.

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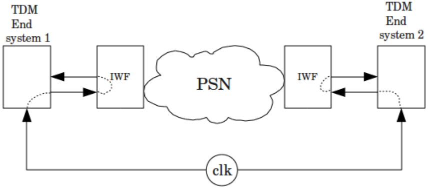
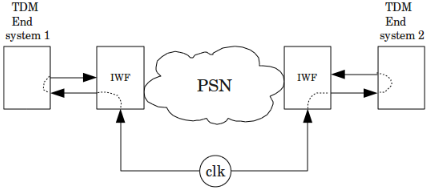
- Solution?
  - Use 'Jitter Buffer'.
  - But still the problem is that 'at what rate data should clocked-out?'
  - ITU-T Rec.Y.1413

Principal Timing Distribution Scenarios

- ITU-T Rec. Y.1413
  - Reference clock available at end systems.



  - Reference clock available at IWFs



Adaptive Clock Recovery

- It is based on TDM traffic only
- It is possible to recover clock since source producing bits at constant rate.
- PDV considered as zero mean random process.

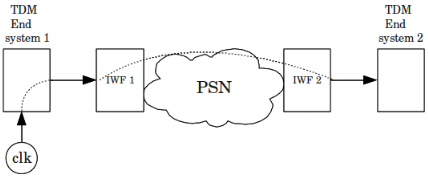


Figure: Adaptive clock recovery

Adaptive clock recovery

- How it works?
  - Instantaneous Packet Delay Variation (IPDV)

$$IPDV(n) = d_n - d_{n-1} \tag{1}$$

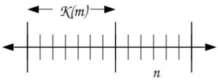
d_n -is instantaneous packet delay

  - Two time scale model.

small scale n is to collect statistics,

large scale m is to estimate delay.

$$k(m) = k_m \tau_n \tag{2}$$



Adaptive clock recovery

$\tau_n = \frac{1}{f_2(n)}$ where $f_2(n)$ is initial estimate of clock

k_m is chosen such that *IPDV* in larger interval is zero

- Frequency difference estimation:
  difference in buffer level from m to m+1 is used to estimate the frequency.

f_1 be clock frequency

frequency perceived at receiver can be written as

$$f_1 + w(n) \tag{3}$$

$w(n)$ is noise frequency(represents PDV in time domain)

Adaptive clock recovery

$$\text{Frequency difference} = f_1 + w(n) - f_2(n) = \Delta f(n) + w(n) \quad (4)$$

let $\theta(n)$ be buffer level

then change in buffer level due to frequency difference is

$$\theta(n+1) - \theta(n) = (\Delta f(n) + w(n))\tau_n$$

$$\Delta\theta(n) = \Delta f(n)\tau_n + \eta(n) \quad (5)$$

where $\eta(n) = w(n)\tau_n$ is noise term(packet jitter)

equation (5) can be written as

$$\Delta\theta(n) = \frac{\Delta f(m)}{f_2(m)} + \eta(n) \quad (6)$$

Adaptive clock recovery

runtime average of $\eta(n)$ is calculated

say it become less than some ϵ for k_m^* intervals

Expectation over larger interval is

$$\frac{1}{k(m)} \sum_{i=n}^{n+k(m)-1} \Delta\theta(i) - \frac{\Delta f(m)}{f_2(m)} = \frac{1}{k(m)} \sum_{i=n}^{n+k(m)-1} \eta(i) \qquad (7)$$

lets define RHS of eq.(7) as

$$X(k(m)) = \frac{1}{k_m^*} \sum_{i=n}^{n+k_m^*-1} \eta(i)$$

Adaptive clock recovery

- so we get optimization problem as

$$k_m^* = argmin_{k(m)}(X(k(m))) \tag{8}$$

for $k^*(m)$ smaller intervals we can write

$$\frac{1}{k^*(m)} \sum_{i=n}^{n+k_m^*-1} \Delta\theta(i) = \frac{\Delta\hat{f}(m)}{f_2(m)} \tag{9}$$

where $\Delta\hat{f}(m)$ is estimate of $\Delta f(m)$

we can write $\theta(m+1) - \theta(m) = k_m^* \dfrac{\Delta\hat{f}(m)}{f_2(m)}$ (10)

Adaptive clock recovery

- Recovered frequency is updated as

$$f_2(m+1) = f_2(m) + \alpha \Delta \hat{f}(m) \tag{11}$$

let estimation error will be,

$$\Delta \tilde{f}(m) = \Delta \hat{f}(m) - \Delta f(m) \tag{12}$$

so final equation becomes

$$f_2(m+1) = (1-\alpha) f_2(m) + \alpha f_1 + \alpha \Delta \tilde{f}(m) \tag{13}$$

for stability $0 < \alpha < 1$

Packet Loss

- Causes:
  - Bit error invalidating data.
  - Intentionally dropped packets due to congestion.
- But in order to maintain timing SOMETHING must be output towards TDM interface when packet is lost.

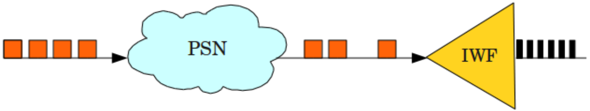


Figure: Packet loss

Packet Loss

- Packet Loss Concealment methods:
  - Replay
  - Interpolation
- Measure of voice quality (Mean Square Opinion)

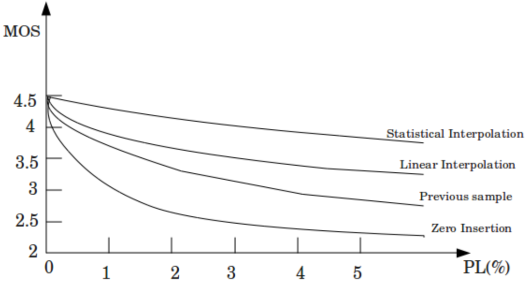


Figure: Effect of different Interpolation techniques[4]

Out-of-sequence packets

- Causes:
  - Parallel paths between the routers which are aggravated by load balancing mechanism.

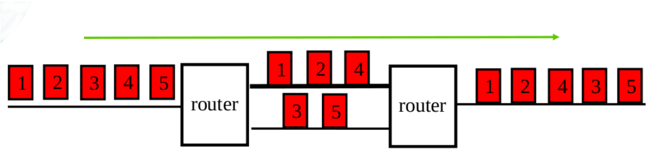


Figure: out-of-sequence packets

- Can be handled by:
  - Reordering(From jitter buffer).
  - Handling as packet loss and dropping latter.

Application

- Cellular Backhauling
  - Connectivity between BTSs, BSCs, and MSC is achieved by using microwave links and T1/E1 leased lines.
  - But it requires higher cost and maintenance.
  - In rural areas and low density areas it not possible to establish microwave links, so we can use wireless backhauling.

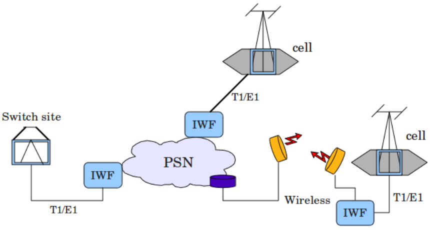


Figure: Cellular Backhauling

Conclusion

- It is possible to attain TDM goals over IP by suitable clock recovery algorithms without much changing the underlying TDM infrastructure.

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- It is possible to attain TDM goals over IP by suitable clock recovery algorithms without much changing the underlying TDM infrastructure.
- By introducing TDMoIP, convergence of access network to unique medium(i.e. Ethernet) is possible

References

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