Synchronisation in the Broadcast Industry

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Disclaimer: author's view of the world

Background

- Move to IP-based production infrastructure for video and audio
- Based on synchronous systems
  - Switchers, mixers, cameras control units, video servers, …
- Currently relies on SMPTE ST-12 Timecode
  - One of the oldest and widely used standards
- Video relies on Genlock or Tri-level sync
- Audio relies on Wordclock or AES-11 (DARS)
- Typically delivered over the Synchronous Digital Interface (SDI) which carries uncompressed digital video, embedded audio, ancillary information and clock/time information

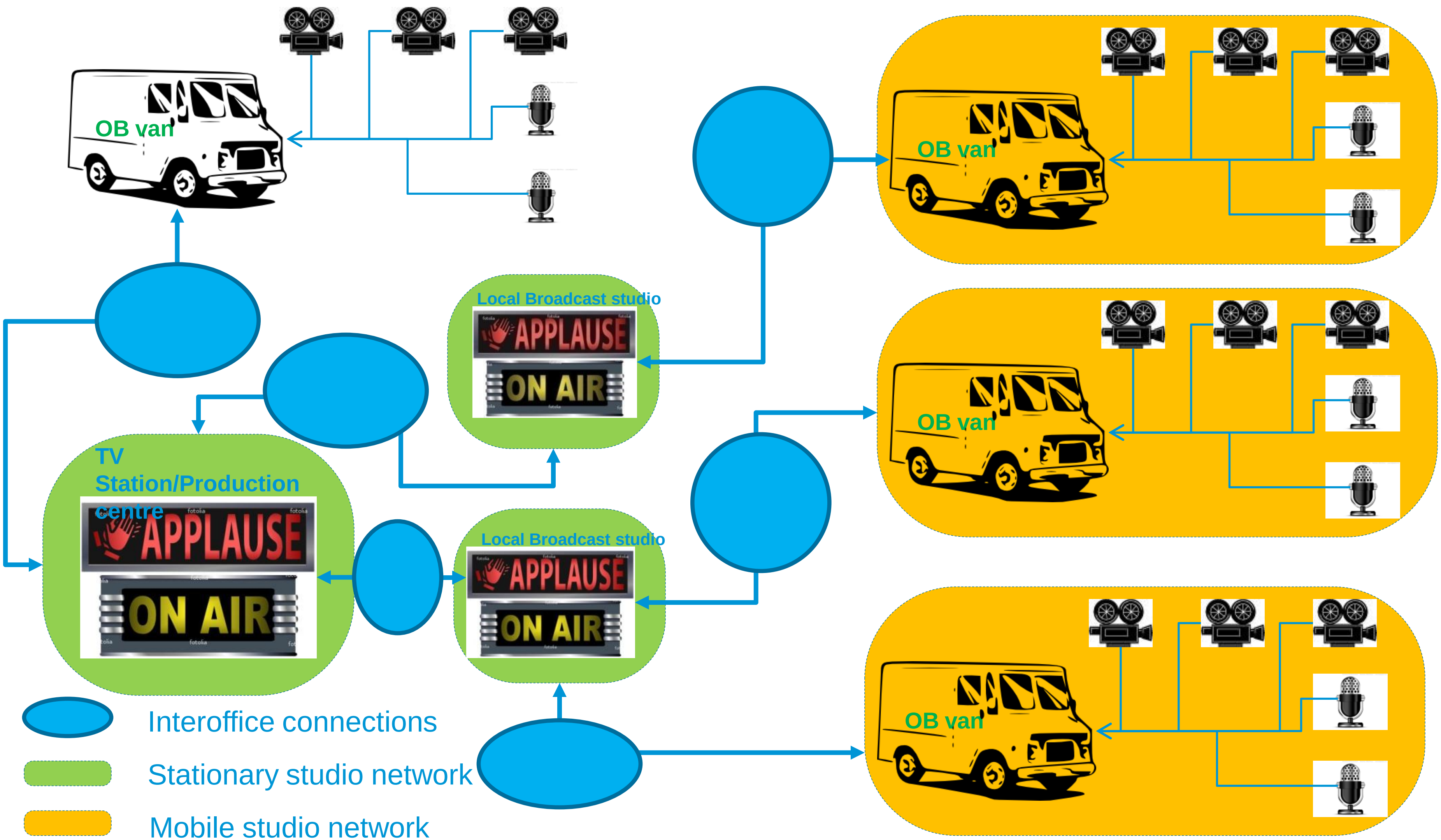
Broadcast production 101

- Content is either live (news, sports) or recorded
- Outdoor broadcast (OB) trucks/vans - to capture events in locations without pre-installed equipment, or connecting to 3rd party equipment
- Small(ish) stationary studios or TV stations - to connect to stationary equipment or OB truck
- TV plant/station - Shot live in studio (news cast, morning show), play out to air live or pre-recorded content

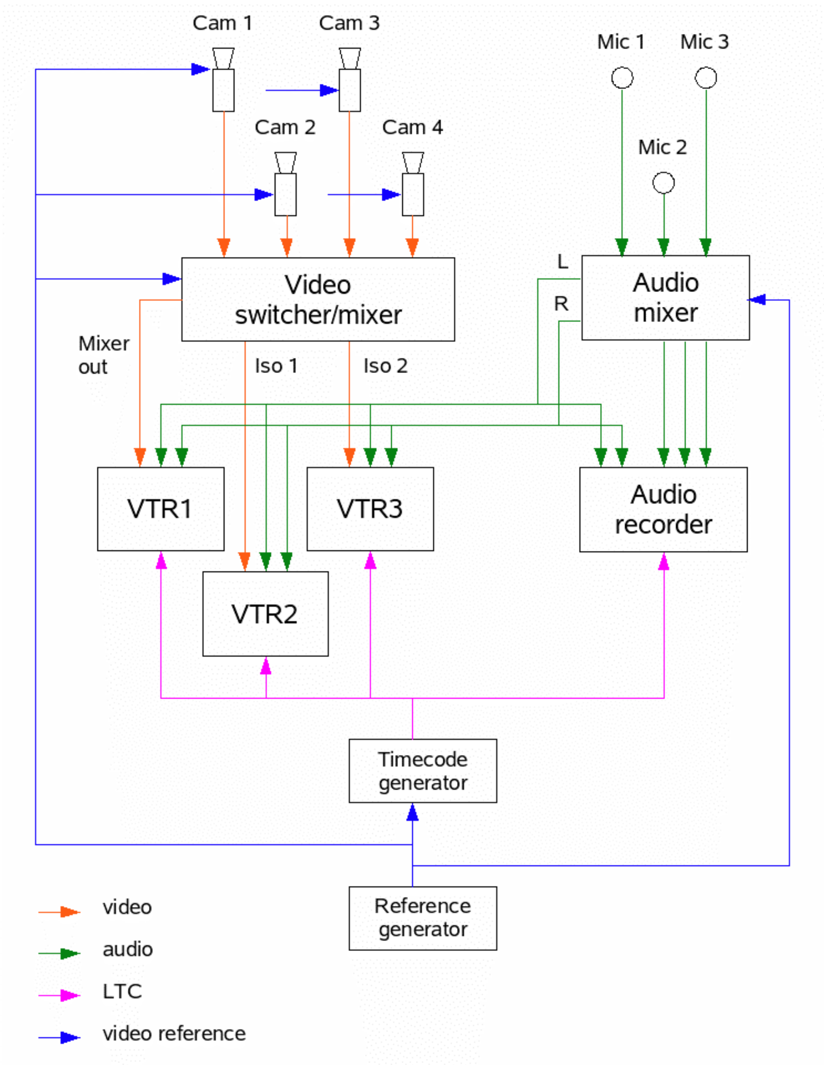
Video frame rates

- From Hollywood
  23.978 (24/1001), 24Hz
- From Europe
  25, 50Hz
- From the US
  29.97 (30/1001), 30, 59.94 (60/1001), 60Hz
- For the future Ultra High Definition systems (4K and 8K)
  48, 96?, 100?, 120, 300?Hz

Broadcasting Production Topology



Current view of OB van/Stationary studio



VTR – Video Tape Recorder.
Original equipment which gets replaced by digital servers but the name stays for now.

***Excerpt from RFT_270208**

So why the need for change?

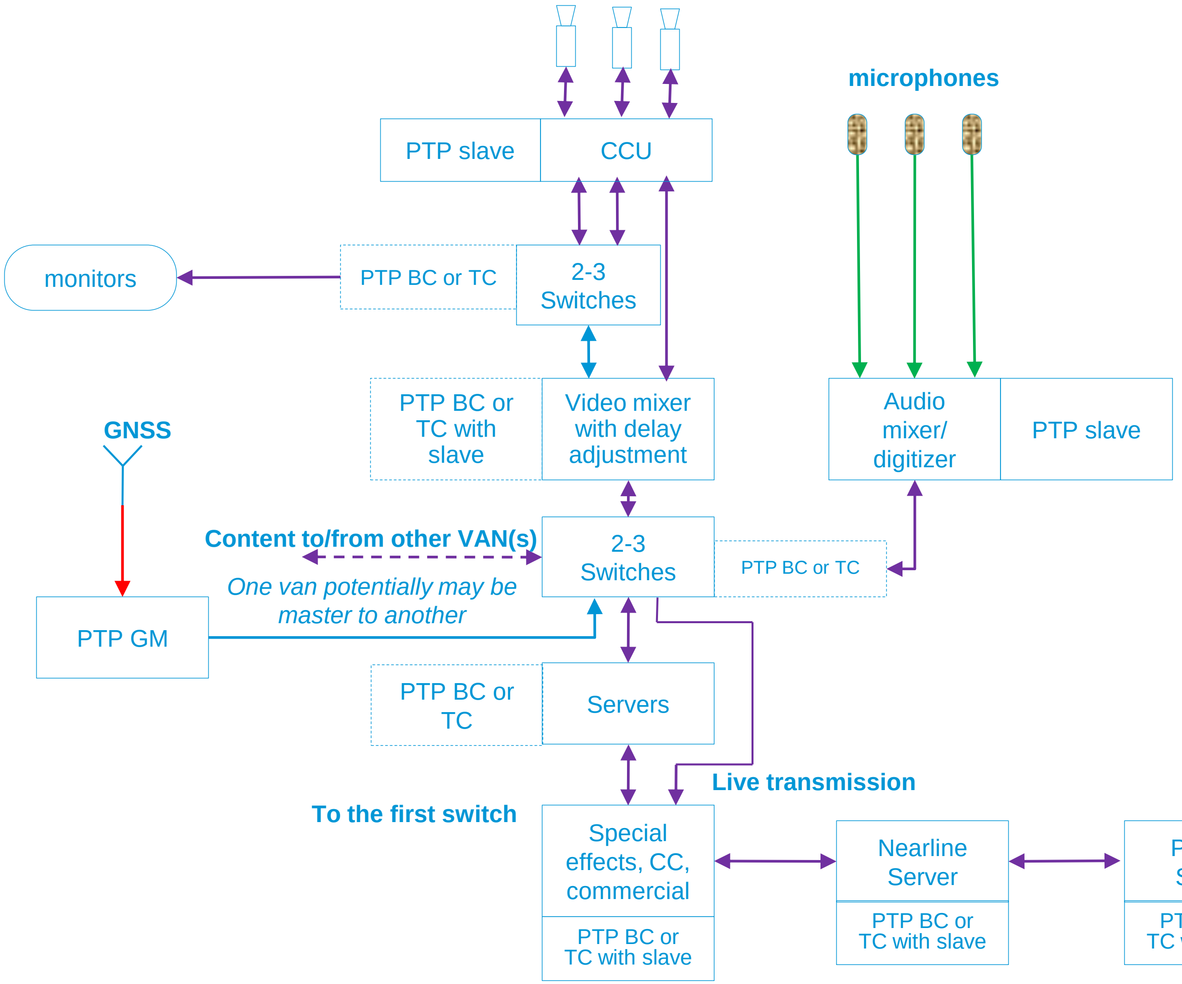
- Cost, complexity of infrastructure
- Multiple distributions required
- Inflexibility – have to pull cables everywhere
- Many single points of failure
- Analogue susceptibilities (legacy)
- Shift in technology

Transition to a new network

- Some cameras, video tape recorders (VTR)/digital servers and phase synchronizers are Ethernet ready
- Each camera and microphone have individual connections to the mixer
- Massive amount of cabling is done in each studio
  - **Each** camera control unit (CCU) has video cable, synchronisation cable and sometimes separate Continuous Time code. May also include return video.
  - The audio is digitized in the audio mixer. The mixer receives Digital Audio Reference Signal (DARS) via **separate** cable
- IP based connections for **all** cables could be replaced by a single one
  - Data, distribute timing synchronisation over the same connection
- Audio and video mixers are still not network ready.

  Mixers are mandatory part of broadcast production
- Impossible to switch to the pure IP based technology without mixers been IP based

OB van: possible next gen simplified view



BC – boundary clock
TC – transparent clock
GM – grandmaster
GNSS – Global Navigation Satellite System, ex. GPS/GLONASS/Galileo
CCU – Camera Control Unit

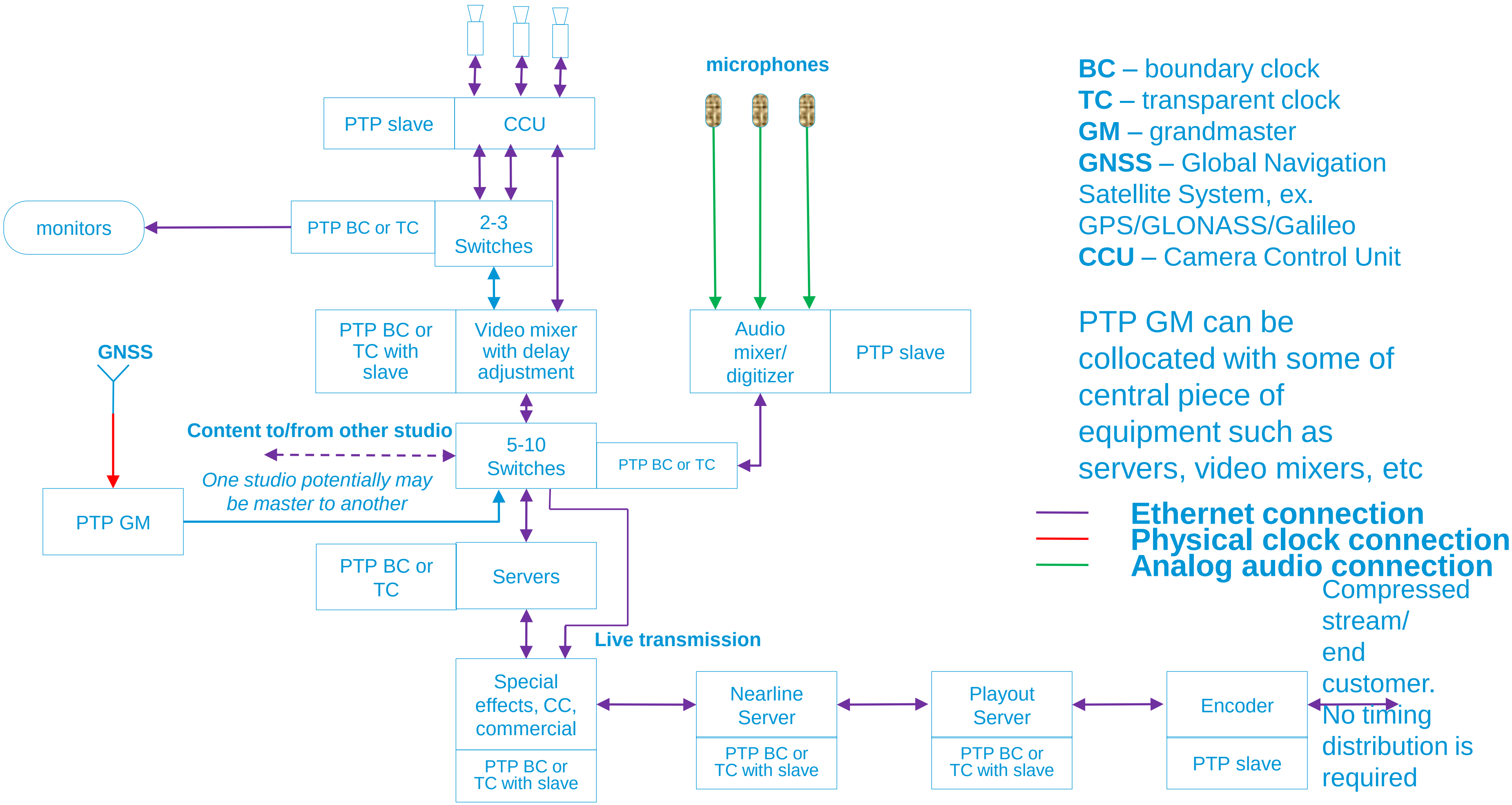
PTP GM can be collocated with some of central piece of equipment such as servers, video mixers, etc

Ethernet connection
Physical clock connection
Analog audio connection

Compressed stream/ end customer. No timing distribution is required

Due to small number of switches and high probability that these are L2 hardware based switches, the on-path support such as BC or TC in the switches may not be required

Small studio



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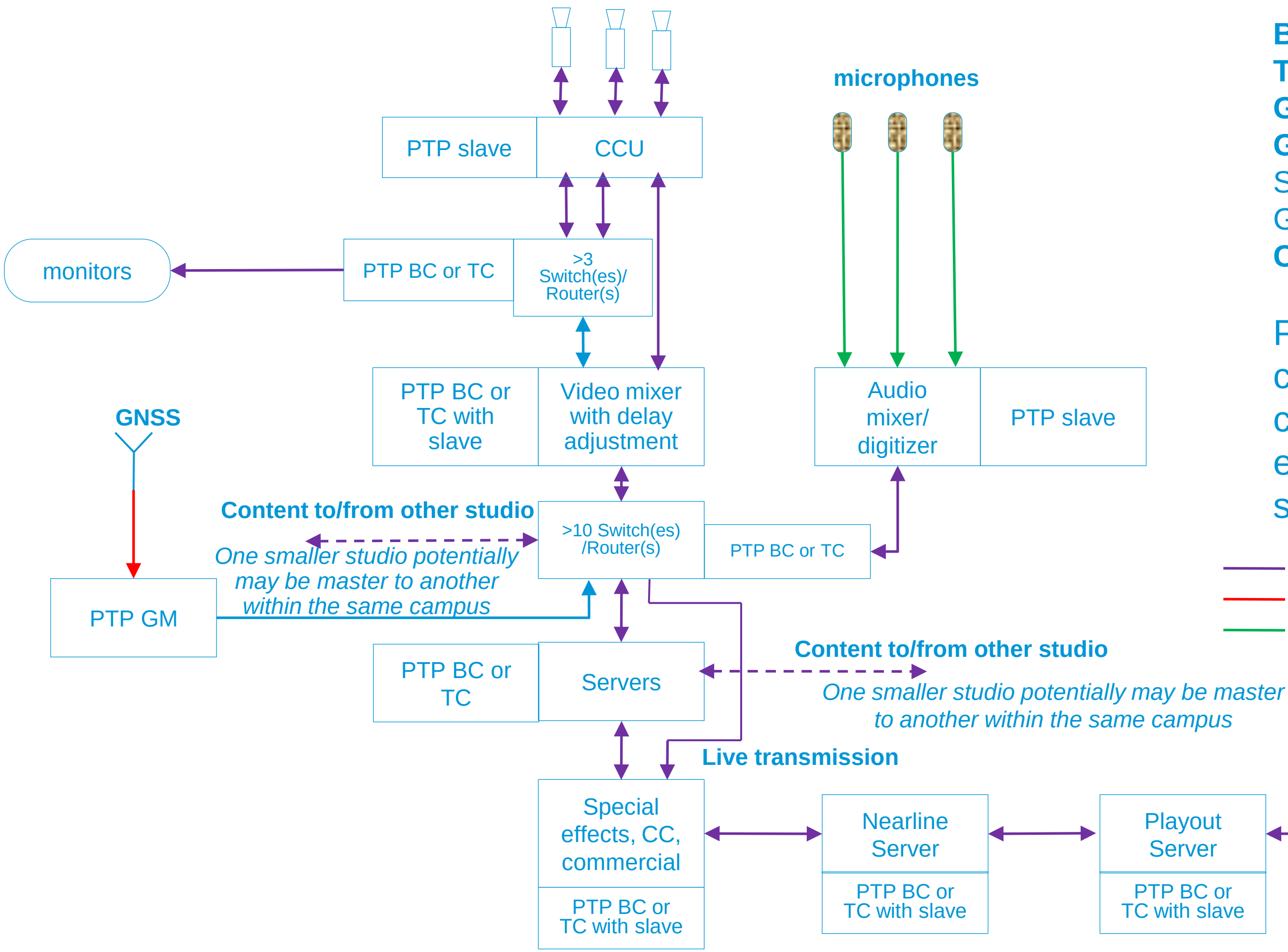
Due to potentially high number of switches the on-path support such as BC or TC in the switches would be required

Large studio



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Physical clock connection
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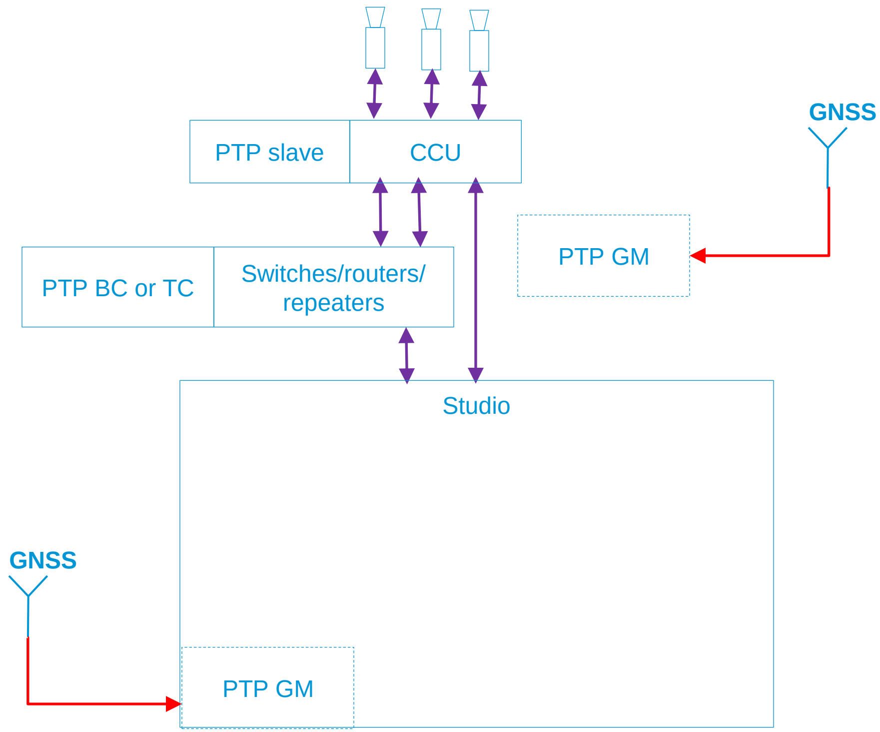
Remote production / External production

Remote stationary facilities permanently connected to the studio



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PTP GM can be collocated with some of central piece of equipment such as servers, video mixers, etc

Due to potentially high number of switches or possible use of routers the on-path support such as BC or TC in the switches most likely would be required

Synchronisation in studios

- Studios are synchronised very tightly
  - For analog composite signal the alignment is 0.5ns
  - For digital signal the alignment is +/-1.5us
  - Frame synchronisers allow up to tens (ex, one frame or +/-32us) of microseconds of misalignment between cameras
- All studios use frame synchronisers to align cameras
  - Frame synchronisers compensate cable length differences between cameras
  - Also adapt input rate from cameras to the common output rate by removing some frames if input rate is faster or replaying the same frame if input rate is slower
- Frame synchronisers are often built into video multiplexers
- Synchronisation within studio must happen practically instantaneously – 5 second target.
  - Important to provide means for eliminating packet delay variation (PDV) and asymmetry effects within studio network

Benefit of precise synchronisation

- Having all cameras running at the same frequency and the same time would provide means to eliminate frame drops/replays
- Having common time at all cameras would allow simple timestamping without a mandatory link to the number of frames, if required.
- Common time would simplify conversion between different video systems (ex. 50/60 Hz).
- Common time would allow simple storage and replay of the video content

Potential future network within TV studios

- Network within small studios or OB vans is expected to be small in terms of number of hops. Distances however can achieve several hundreds of meters. The connections are expected to be copper but optical is possible.
- Some cameras use microwave links which makes packet based synchronization more complicated and would require special attention.
- Normally single event is covered by 5-6 cameras. Major events can have up to 12-15 cameras.
- In case of HD-SDI each camera takes 1.5 Gbps. 3G-SDI requires 3 Gbps. 3D video requires 6Gbps.

Potential future network within TV studios (continue)

- 12 cameras (3G-SDI) would take 36Gbps. There is no 40G pipes currently used at broadcasters facilities. Therefore each camera is still expected to have individual connection to the video mixer.
- Ethernet connections would allow having up to 3 of these cameras going through a single 10G switch within a stage perimeter and then connect to the video multiplexer with a single cable. This is an option but such details are not discussed yet.
- Majority of connections within studios are 10G copper. But optical is frequent too
- New Ultra HDTV cameras will use 72Gbps (or higher) and will require 100Gbps connection (or higher)
- Replacing copper connections with a optical would allow studios to scale from 1G to 40G or even 100G without major investment into cabling infrastructure

Inter-studio connections

- Some major events locations such as large stadiums are hardwired to TV stations or production facilities via optical fiber
- If location of broadcasting is relatively random then the transmission from OB truck to TV station could be microwave or satellite.
    - Follow the information flow. News happens anywhere
- Connections between local TV stations and headquarters most often use optical fiber

GNSS based sync for all stations

- GNSS is considered as a main source of the synchronization.
- In case of loss of GNSS signal the high stability oscillator Oven Controlled Crystal Oscillator (OCXO) is required in order to keep the synchronization intact for a day or two.
- For longer periods (several days/weeks) Double Oven Controlled Crystal Oscillator (DOCXO) or Rb oscillator with even better stability parameters would provide the expected stability.

Note: Telcordia GR1244 and ITU-T G.811, G.812 define several levels of reference clock quality. Rb clock is Stratum 2 (Telcordia definition) with $\pm 1 \times 10^{-10}$/day holdover stability and good DOCXO can achieve Stratum 3E holdover stability of $\pm 1.2 \times 10^{-8}$/day

PTP options for inter-studio synchronization

- The cost of the oscillator is not prohibitive even for the OB trucks.
  - It is possible to use Rb or DOCXO at the central sync generator at the studios.
  - Considering long time for the proper warm-up and power consumption of Rb and DOCXO oscillators, would it be possible to keep those oscillators powered either all the time or for a sufficiently long time before the actual use?
    If so, then, for example, OB truck can be synced quickly within the studio and then hold accurate time during the trip to the event
- The precision of the time synchronization between studios is not as critical as in intra-studio case.
  - Central studios would compensate for the delays anyway
  - long time loop is possible in order to compensate for a satellite connections
- Controlled environment
  - PTP slaves can be temperature stabilized in the central sync generators

SMPTE TC-33TS20

Society of Motion Picture and Television Engineers,
Synchronization Working Group

The goal:

The application of the general scope as it applies to the definition of time labeling of essence and the synchronization of systems and essence in both digital and analog forms over networked and streaming transports.

The reasons for new standards

- Current reference signals are about 30 years old and are based on color black and time labeling and requires a dedicated infrastructure
- No support for multi frequency standards, i.e. needs to have different color black for different frequencies
- Not easy to sync audio and video....
- Digital packet based timing distribution in multi-standard media creation and production environments allows overcome these limitations. Support arbitrary frame rates, ms, µs etc.
- New sync signal not tied to old analog technology
- Independent of audio/video standard
- Ethernet transport (and possibly others)
- Sync also carries global time, i.e. no need for separate LTC feed to camera

Ongoing work assumptions

- Goal is to design a IEEE 1588 “SMPTE Broadcast profile”
- Focusing on layer 3 approach
  - IPv4 and IPv6 support
- Support unicast and hybrid
  - Possibly thousands of “genlocked” devices on a TV station campus
- Support “Administratively scoped IP Multicast” and “Source Specific Multicast”
  - 239/8 range in IPv4 and FF3x::/32 in IPv6
  - Source Specific used for typical multicast based workflows
  - Avoid (re)introducing legacy “Any Source Multicast” due to 1588 IANA registered multicast addresses

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