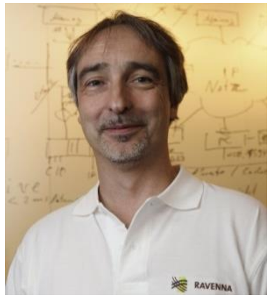
Synchronization of ST 2110 Audio

- Andreas Hildebrand –

RAVENNA Technology Evangelist

ALC NetworX, Munich



Andreas Hildebrand, RAVENNA Technology Evangelist

- more than 25 years in the professional audio / broadcasting industry
- graduate diploma in computer science
- R&D, project & product management experience
- member of AES67 TG and ST2110 DG

ALC NetworX GmbH, Munich / Germany

- established 2008
- R&D center
- developing & promoting RAVENNA
- Partnerships with > 40 manufacturers

RAVENNA

- IP media networking technology
- designed to meet requirements of professional audio / broadcasting applications
- open technology approach, license-free
- fully AES67-compliant (*built-in*)

Timing & Synchronization – General Requirements

- Media bit-transparency
  - → no sample rate conversion
  - → streams need to run on same media clock
- Concurrent operation of different sample rates on same network
- Determinable (low) end-to-end latency
- Time alignment between media streams
- Replacement for "house clock" distribution (word clock, black burst etc.)

⇨ Clock reassembly from stream data not appropriate
⇨ Distribution of master clock beats not sufficient
⇨ Common understanding of absolute time required ("wall clock")

Timing & Synchronization – Accuracy Requirements

- Audio applications have highest time accuracy & precision demands:
  - ⇨ Sample accurate alignment of streams (± ½ sample)
    - @ 48 kHz: ± 10 µs
    - @ 96 kHz: ± 5 µs
    - @ 192 kHz: ± 2.5 µs
  - ⇨ "Distribution" of word clock reference
    (AES11 calls for ± 5% max jitter / wander):
    - @ 48 kHz: ± 1 µs
    - @ 96 kHz: ± 500 ns
    - @ 192 kHz: ± 250 ns

Synchronization & Media Clocks

- All nodes are running local clocks
- Local clocks are precisely synchronized to a common wall clock via IEEE 1588-2008 (PTPv2)
- *PTPv1 standardized by IEEE in 2002 (IEEE 1588-2002)*
  PTPv2 followed in 2008 (IEEE1588-2008)
  PTPv1 and PTPv2 are not compatible!

How PTPv2 works

- Nodes are organized in a master/slave hierarchy
  The grandmaster is at the top, it is elected according to clock quality.
- Grandmaster multicasts periodic sync messages
  Clients learn the grandmaster time, and correct their own time.
- Transmission delay is measured with a delay_request / delay_response message pair
  Measured delay is used to correct the time extracted from the sync message.
  Delay measurement can be very accurate with support from switches (BC or TC).
- Received grandmaster time is used to drift-compensate local clock
  Local clock can be a disciplined oscillator (VCO or VCXO),
  or it can be a free-running clock with digital correction (more common).
- Local clock in each node is used to timestamp PTP messages
  Highest precision requires hardware timestamping support in a node, either in the PHY, or in the MAC, or in-between (the closer to the wire the better).

Grandmaster Selection

- The standard defines a common Best Master Clock Algorithm (BMCA)
  Every node follows the same algorithm → all arrive at the same result.
- Every node holds a data set describing the qualities of its own clock
  There are several different quality criteria which are considered.
- Data sets are distributed in the network with *Announce* messages
  All nodes know data sets of any other node and can compare against their own sets.
- BMC Algorithm is re-run when current grandmaster disappears
  There is a period of time without sync messages until the new grandmaster takes over. The clients must be able to bridge the gap.
- Grandmaster does not need to be a “dedicated” GM device
  Master capability can be a function of an ordinary node.

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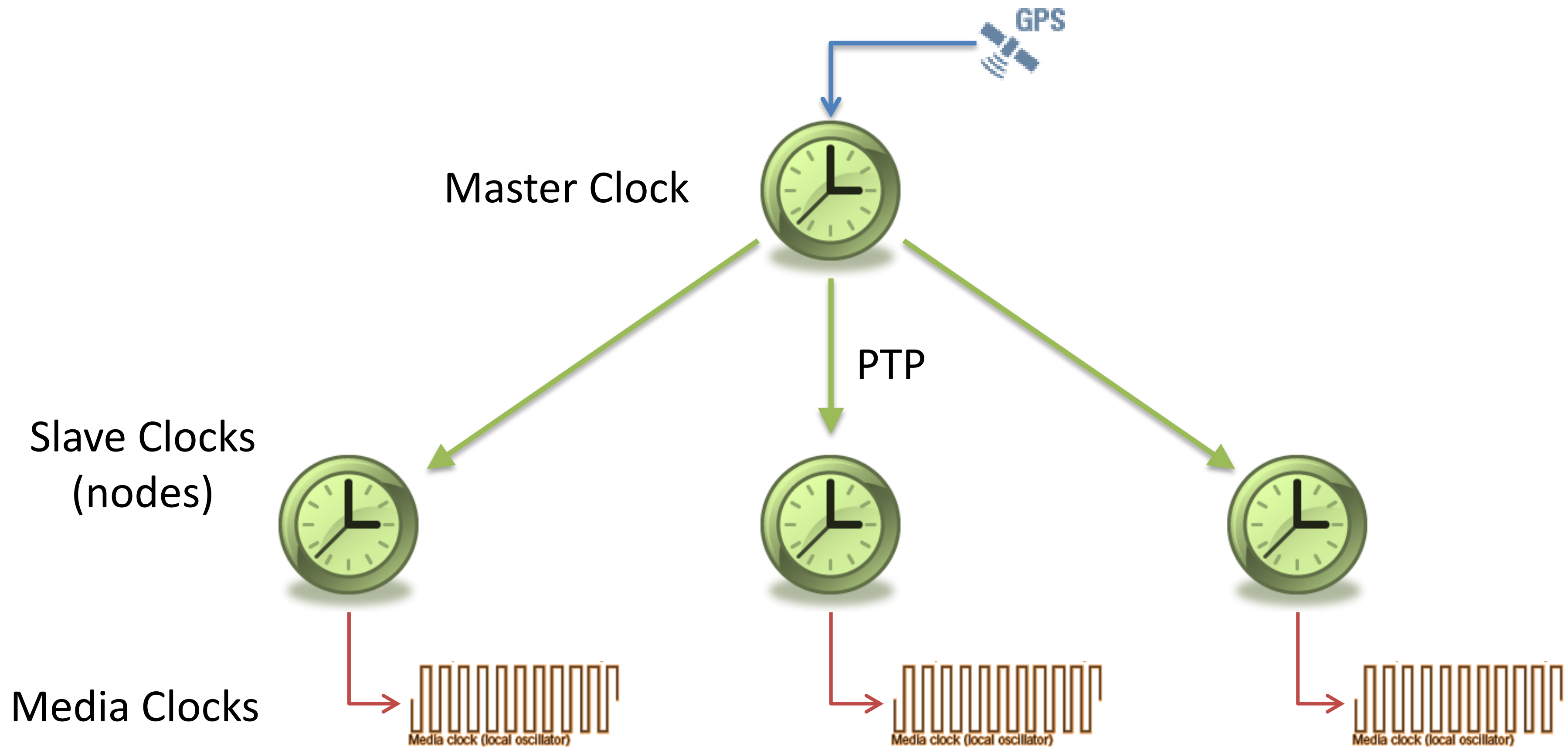
Synchronization & Media Clocks



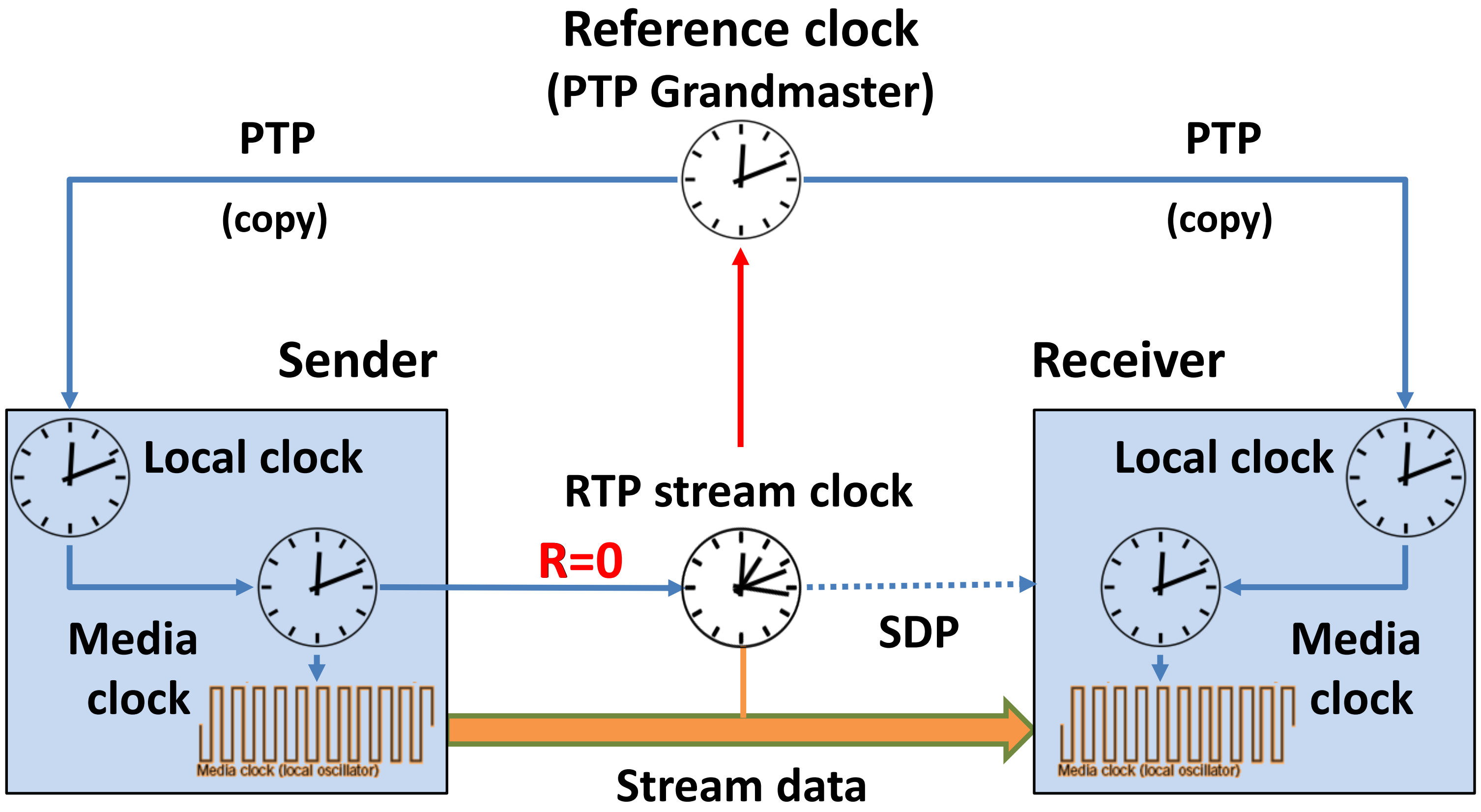
Synchronization & Media Clocks

- All nodes are running local clocks
- Local clocks are precisely synchronized to a common wall clock via PTP
- Media clocks are generated locally from synchronized local clock
- Generation of any desired media clock (sample rate) possible
- Concurrent operation of different media clocks possible
- Phase accuracy of AES 11 (± 5% of sample period) achievable
  by deployment of PTP-aware switches (BC or TC)
- Synchronization across facilities possible by reference to absolute time (TAI / GPS)
- Essence data (audio samples or video frames) is related to the media clock upon intake
  - essentially receiving a generation "time stamp" with respect to the media clock (network clock)

Synchronization & media clocks

- 3 type of clocks in the system:
  - Wall clock (reference clock) - provided by Grandmaster
    - local copy of the wall clock in each node
  - Media clock – derived from the local clock (i.e. 48 kHz for audio, 90 kHz for video)
  - RTP clock (stream clock) – derived from the media clock

Synchronization & media clocks

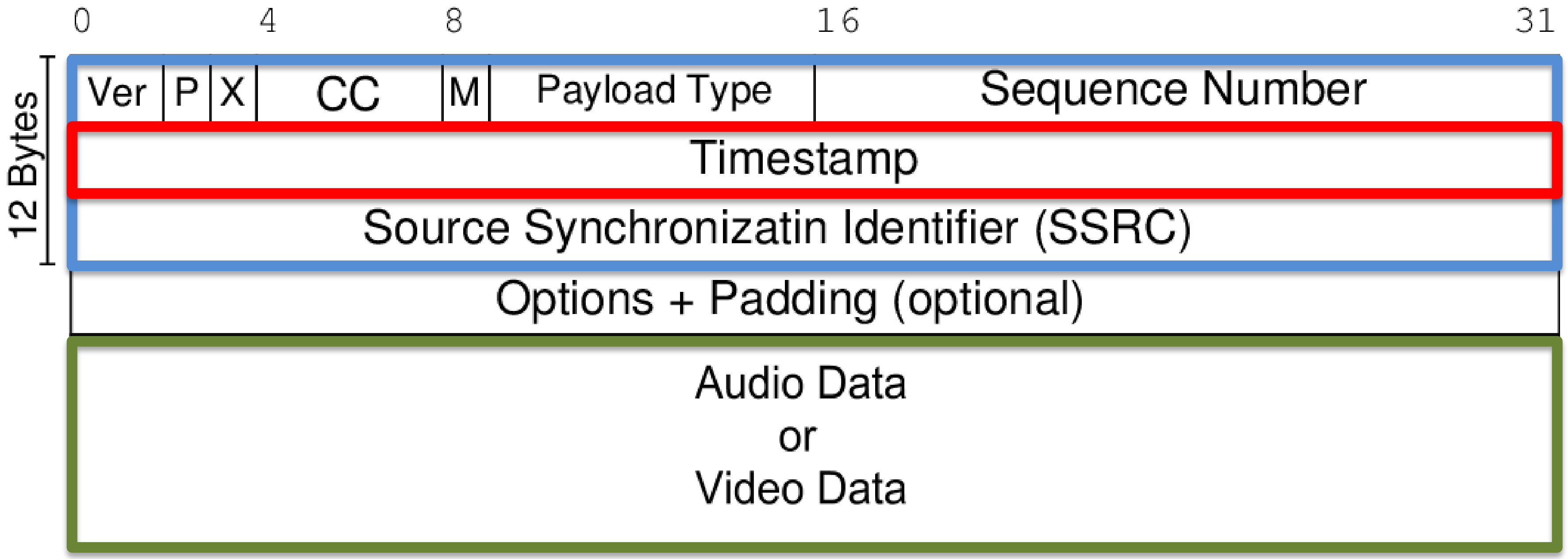


- Offset **R** is established on stream start-up
- **R** may be random to defeat crypto-text attacks
- This offset will be constant throughout the stream's lifetime

- The offset (**R**) will be conveyed via SDP (a=mediaclk:direct=<offset>) **– must be "0" in ST2110**

RTP Packets (Layer 5)

- Consist of RTP header, optional payload headers and the payload itself
- RTP header (overhead) = 12 bytes, payload (linear audio data) = up to 1440 bytes
- RTP Timestamp = media clock counter (for linear PCM audio) = 32 bits (4 bytes)



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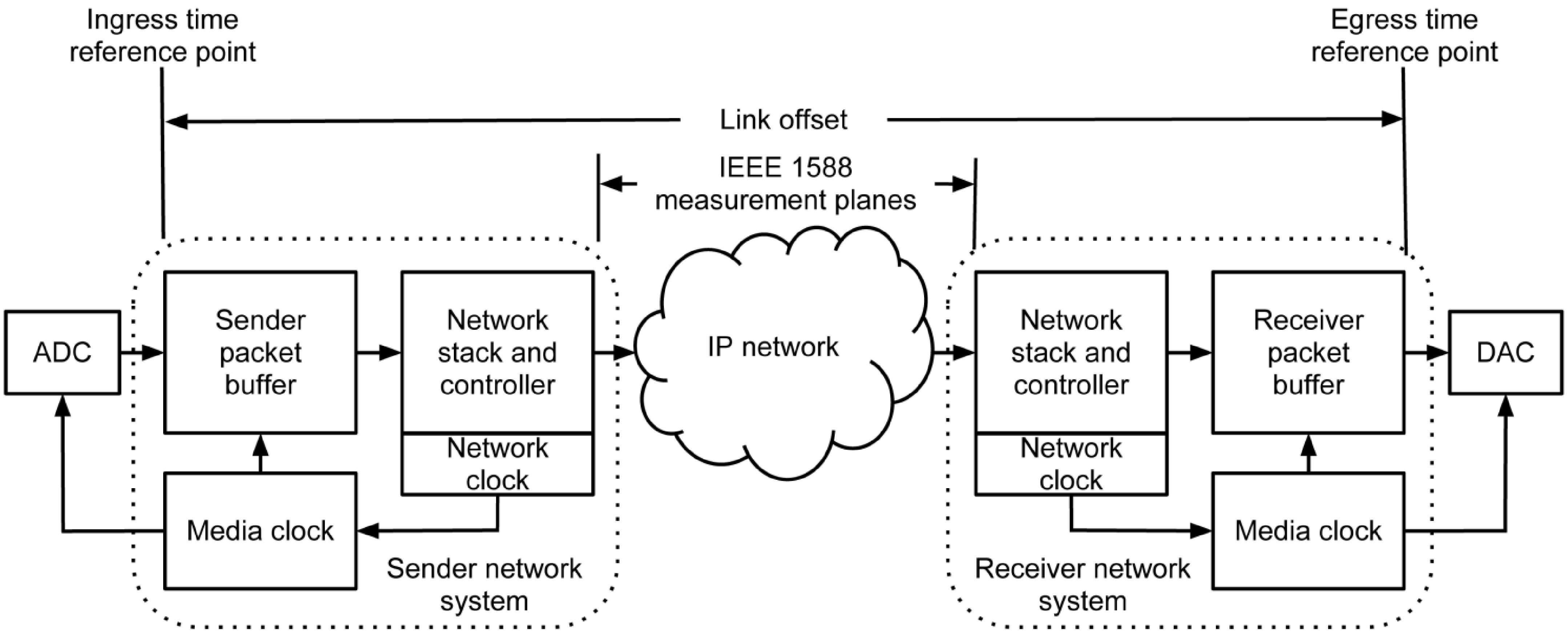
- Fixed / determinable latency by configuring a suitable link offset (“playout delay”)

Synchronization & Media Clocks - Link offset



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- Inter-stream alignment by comparing and relating the time stamps of individual essence data

Production Workflow Timing

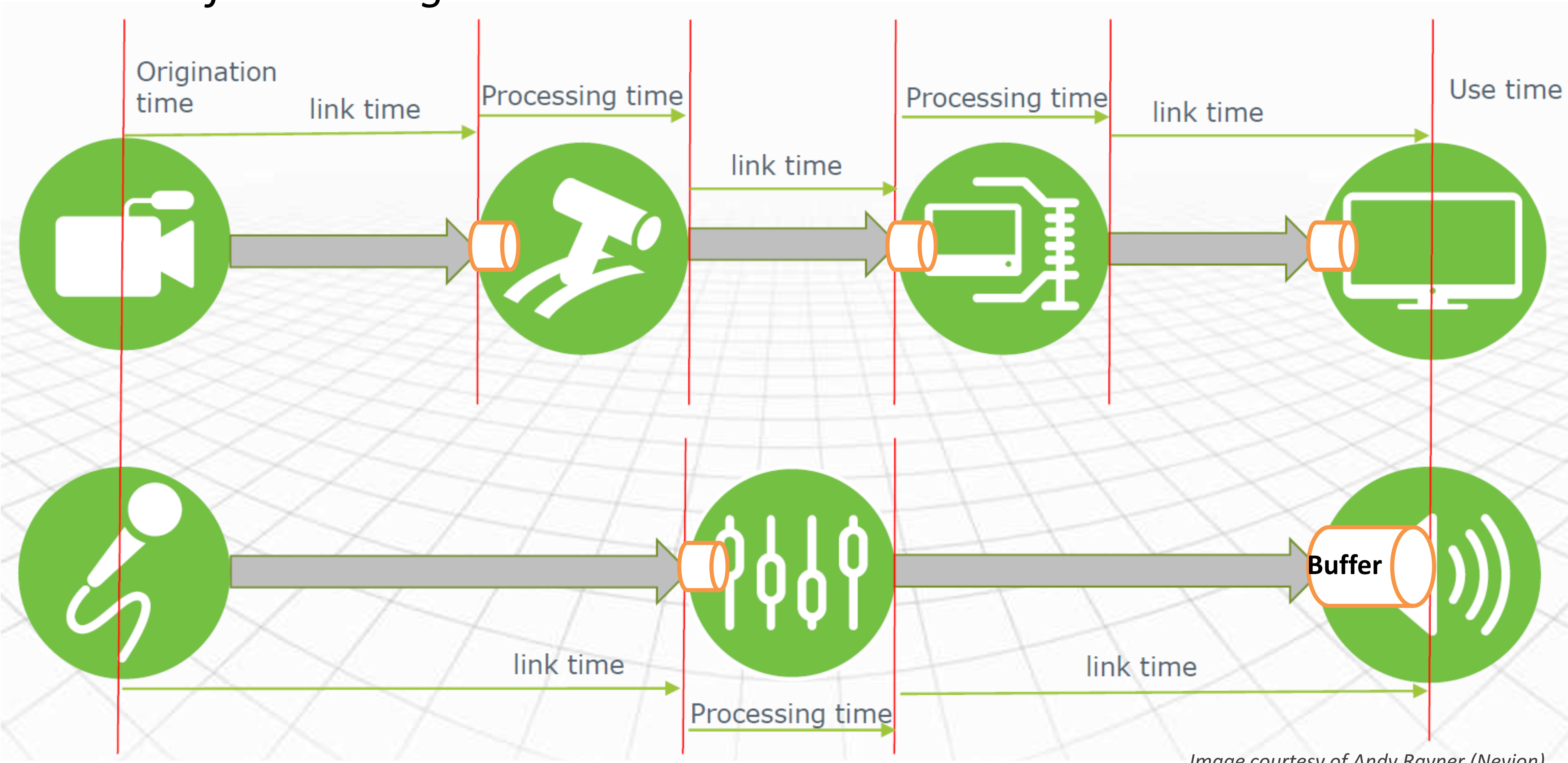

Image courtesy of Andy Rayner (Nevion)

How to synchronize streams across various processing stages

- Problem:
  - Any stream leaving a (processing) device is a new stream
  - New alignment of (processed) essence to wall clock (reference) time
  - Alignment of original essence is lost
- Possible solutions:
  - Use of original time alignment for new stream (RTP timestamps adjusted to those of original essence)
    - Offset increases, might be too large for downstream Rx buffer
    - Which timestamps serve as reference when mixing essence?
    - How does the (processing) host know the exact relationship between ingress / and egress essence?
  - Carry origin timestamps as in-band meta data
    - Requires new payload format (audio essence data + audio meta data), or
    - Needs to make use of RTP header extensions mechanism
      (which in turn may result in variable / decreased audio payload segments)
  - Carry origin timestamps as out-of-band meta data
    - Requires new standard (in the works → **AES X242, ST2110-41/-42, NMOS**)

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- Intermediate (?) / current solution:
  - Leave alignment task to management layer (i.e. Broadcast Controller)
    - Devices report processing delays to BC (or have fixed / configurable delays)
    - BC configures required Rx delay for subsequent stages (playout delay)

Production Workflow Timing

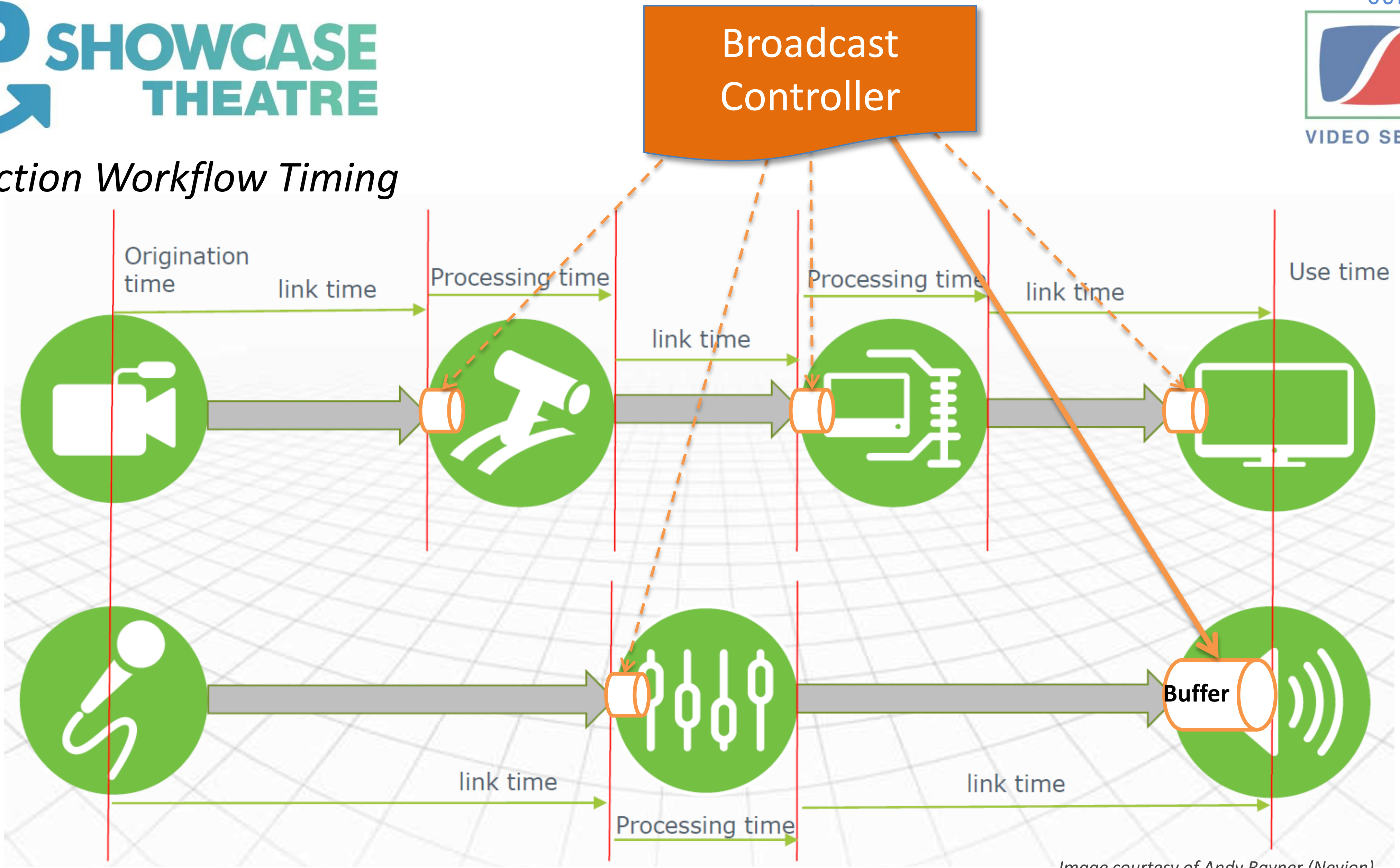

Image courtesy of Andy Rayner (Nevion)

Thank you for your attention!

RAVENNA booth North Hall
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