Residential Ethernet Objectives, Requirements and Possible Solutions

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Agenda

• Background
• Derivation of requirements
• Current approaches
  – and problems
• Proposed solutions
  – emphasis on bridge-based mechanism(s)
Residential Ethernet Background
Before we start ...

• Please defer all discussion about *where* in 802 the whole of “Residential Ethernet” needs to be specified
  – Some ideas on layering are at the end
• Treat “Residential Ethernet” as an 802-based system that will typically be implemented on top of “Ethernet”

Thanks!
Scope (from July ‘05 CFI)

- Residential Ethernet provides time-sensitive delivery between plug-and-play stations over reliable point-to-point full-duplex cable media. Time-sensitive data transmissions use admission control negotiations to guarantee bandwidth allocations with predictable latency and low-jitter delivery. Device-clock synchronization is also supported. Ensuring real-time services through routers, data security, wireless media, and developing new PMDs are beyond the scope of this project.
Purpose

• To enable a common network for existing home Ethernet equipment and locally networked consumer devices with time-sensitive audio, visual and interactive applications and musical equipment. This integration will enable new applications, reduce overall installation cost/complexity and leverage the installed base of Ethernet networking products, while preserving Ethernet networking services. An appropriately enhanced Ethernet is the best candidate for a universal home network platform.
ResE objectives for 802

- All plug and play features required, not optional
  - CE industry requirement for minimal options and configuration
- Admission controls to guarantee path bandwidth
  - If a stream is started, it must continue to work
- Isochronous and best-effort traffic will be carried together, with some bandwidth reserved for best-effort
  - Always need some bandwidth for control
- Links will be 100Mb/s full duplex or greater
  - Standard frame on 10Mb is too long (1.2ms) and adds to latency
  - Most common CE stream will be HD video @ 20Mbit/s
  - Full duplex allows bridge-based QoS services without compromise
ResE objectives for 802 (2)

- Isochronous traffic will have less than 2ms end-to-end latency through the entire network and only 250μs through one hop
  - Worst case for CE application is musical instrument (see following presentation)
  - Seems to be “free” for implementations

- Delivered isochronous traffic will have very low jitter and wander approaching zero
  - Minimizes buffer and filtering requirements for applications
ResE objectives for 802 (3)

• High quality synchronization services will provide all stations with a low jitter “house clock”
  – Applications need a good time stamp source
• Support for all 802.1 services, in particular 801.1Q VLANs
  – ResE will be used in shared housing (e.g., apartment buildings)
• Support arbitrary topologies within reasonable limits (802.1D RSTP and follow-ons)
  – … minimize configurations that “don’t work”
• backbone for IEEE 802.11 and IEEE 802.15.3 such that all QoS parameters are respected
ResE objectives for "other groups"

- Isochronous bridging to IEEE 1394
  - take advantage of wide experience and standardization
  - support IEC 61883 payloads (MPEG/DV/digital audio)
  - "DCAM" machine vision cameras (uncompressed)

- Perhaps even bridging to USB, MOCA, and higher level protocols such as RTP
  - additional “isochronous” payload types
... and one more thing ...

• All objectives must be met at “virtually no cost”
• For CE companies, this means that if it can be done using 100-base TX PHYs, then that’s what they want

And there are strong arguments that it can be done
Detailed requirements

• Compatible with existing* and planned 802.1 and 802.3 standards
  *at least those that support 100Mbit/sec full duplex and better

• Timing synchronization
  – minimize jitter-induced distortion
  – minimize wander-induced loss of data or excessive buffering
  – guarantee inter-stream synchronization of related data

• Guaranteed low latency for AV streams
  – typical network latency <2ms
  – scalable
    • deterministic based on network topology, not on implementation

• Guaranteed bandwidth for AV streams
  – once connection is made, QoS is consistent and unchanging
## Summary of Jitter/Wander/Synchronization Requirements
(from G. Garner, to be presented 5/17/05 at Austin ResE SG Interim)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Uncompressed SDTV</th>
<th>Uncompressed HDTV</th>
<th>MPEG-2, with network transport</th>
<th>MPEG-2, no network transport</th>
<th>Digital audio, consumer interface</th>
<th>Digital audio, professional interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide-band jitter (UIpp)</td>
<td>0.2</td>
<td>1.0</td>
<td>50 μs peak-to-peak phase variation requirement (no measurement filter specified)</td>
<td>1000 ns peak-to-peak phase variation requirement (no measurement filter specified)</td>
<td>0.25</td>
<td>0.25</td>
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<tr>
<td>Wide-band jitter meas filt (Hz)</td>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
<td>200</td>
<td>8000</td>
</tr>
<tr>
<td>High-band jitter (UIpp)</td>
<td>0.2</td>
<td>0.2</td>
<td></td>
<td></td>
<td>0.2</td>
<td>No requirement</td>
</tr>
<tr>
<td>High-band jitter meas filt (kHz)</td>
<td>1</td>
<td>100</td>
<td></td>
<td></td>
<td>400 (approx)</td>
<td>No requirement</td>
</tr>
<tr>
<td>Frequency offset (ppm)</td>
<td>±2.79365 (NTSC)</td>
<td>±10</td>
<td>±30</td>
<td>±30</td>
<td>±50 (Level 1)</td>
<td>±1 (Grade 1)</td>
</tr>
<tr>
<td>(PAL)</td>
<td>±0.225549 (PAL)</td>
<td></td>
<td></td>
<td></td>
<td>±1000 (Level 2)</td>
<td>±10 (Grade 2)</td>
</tr>
<tr>
<td>Frequency drift rate (ppm/s)</td>
<td>0.027937 (NTSC)</td>
<td>No requirement</td>
<td>0.000278</td>
<td>0.000278</td>
<td>No requirement</td>
<td>No requirement</td>
</tr>
<tr>
<td></td>
<td>0.0225549 (PAL)</td>
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</tr>
</tbody>
</table>
Network Interface MTIE Masks
(from G. Garner, to be presented 5/17/05 at Austin ResE SG Interim)

MTIE - Maximum Time Interval Error - peak-to-peak phase variation for a specified observation interval, expressed as a function of the observation interval.

Network Interface MTIE Masks for Digital Video and Audio Signals

Uncompressed SDTV (SDI signal)
Uncompressed HDTV (SDI signal)
MPEG-2, after netwk transport (Ref. Pts. D and E)
MPEG-2, no netwk transport (Ref. Pts. B and C)
Digital Audio, Consumer Interfaces (S/P-DIF)
Digital Audio, Professional Interfaces (AES3)
Inter-stream synchronization requirements
(from G. Garner, to be presented 5/17/05 at Austin ResE SG Interim)

• Tightly coupled audio (e.g., audio streams delivered to multiple speakers) - 10 µs
• Lip-synch - 80 ms
• Video animation with accompanying audio - 80 ms
• Inter-stream synchronization difficult without network-wide time base
Latency requirements

• Typical human-interface control systems require <100ms response time
  – best if <50ms
  – guess at network budget of 25ms for round trip, or 12ms one way
  – the application(s) will use up the rest

• Worst case control system for home is playing/recording musical instrument(s)
  – not a small market!
Playing music requires timely feedback

Comfort music playing requires delay to be no more than 10 - 15 millisecond*
Home recording

If $T = T_1 = T_2 = T_3 = T_4$ and
\[4 \times T + 2 \times 1\text{ms} + 5\text{ms} + 6\text{ms} < 15\text{ms}\]
Then $T < 0.5\text{ms}$

($T_n$ is total network delay included queuing inside networked device)
Garage jam session

if $8 \times T + 2 \times 1\text{ms} + 3\text{ms} + 6\text{ms} < 15\text{ms}$
then $T < 0.5\text{ms}$
Guaranteed bandwidth for connections

• Typical statement made by CE representatives:
  – “If the network is reaching its limits, denial of service is preferable vs. allowing a new application to disrupt the audio or video quality of another application already running on the network.” Jim Battaglia, Pioneer

• In other words, this is a desire for a connection-oriented QoS
  – “intserv” preferred over “diffserv”

• For applications where statistical QoS is acceptable, then the CE industry will use wireless
Manageability preserved

• Some percentage of bandwidth reserved for best effort traffic
  – proposing 25 %
• using priorities for higher level management as is currently proposed
Existing solutions and problems
"Higher layer" timing synchronization

- Timing synchronization can be done at higher layers
  - NTP and SNTP from IETF
    - slow to converge, insufficiently accurate
  - IEEE 1588
    - measures timing at start of packet launch on media
- 1588 requires that bridges participate
  - using priorities would not work
    - Dirk S. Mohl, “IEEE 1588 - Precise Time Synchronization as the Basis for Real Time Applications in Automation”
    - all would require a 1588 timing element and coordinator
    - drive up the cost of “CE” oriented bridges
- Much easier to do as a service of the MAC (or just above the MAC if the MAC does not introduce any delays)
Guaranteed QoS: Overprovisioning

• Proposal: provide enough network bandwidth to guarantee that AV streams get adequate bandwidth and bridge queues never overflow nor add excessive delay

• Problem: no way to enforce
  – How do you stop a consumer from plugging in a GigE-based PC and using it?
  – How do you guarantee that the consumer won’t start plugging in legacy FE bridges that “mostly” work?
  – How do you guarantee that some future applications don’t outstrip your overprovisioning assumptions?
    • e.g., uncompressed or lightly compressed video, trick play
Guaranteed QoS: add priorities

• Proposal: have AV streams run at a higher priority, combine that with overprovisioning
  – better than straight overprovisioning

• Problems:
  – still require that consumer has a managed network. E.g., unqualified configurations will sometimes work, sometimes not
  – still no guarantee for future applications
  – no guarantee that PC applications won’t start using priorities
    • no rules there!
Proposed enhancements

• ResE SG has three proposals on the table
  – Allow a “hub-like-thing” to be used in GigE to switch streams in real time (Spyder)
  – Use a variation of the EPON timeslot management
  – Add real-time or scheduled priority gating to bridges

• The first two do not address how the enhanced QoS gets through bridges
  – And that *is* a requirement for a total solution
  – PERSONAL preference is to solve a problem just once
  – So that’s what I’m talking about here
Goals for bridge-based solution

• meet requirements
• minimal additions
  – use 802.1 and 802.3 mechanisms and layering
• easy to implement
• easy to specify
• scalable
  – useful for all MAC/PHY combos that have similar performance (>= 100Mbit/sec, full duplex)
  – useful in all kinds of cascaded bridge environments
Bridge-based synchronization?

- Run 1588-like protocol at the MAC layer or just above
  - precise measurement of launch of packet
  - implement on output port *after* any queuing
  - could be MAC addition, but requires change to MAC services or another MAC control layer
- Run 1588 master selection/grand master selection at LLC level as a bridge protocol
802.1-based admission control

- Control protocol using some much simplified RSVP - “SRP?”
- Specific labeling of "AV" streams so admission control can be enforced
  - Use “well known” multicast addresses
    - AV streams are frequently multicast anyway
  - Interesting project for protocol to assign addresses without using a centralized server
- Enforcement of limits on bandwidth usage at output ports
  - limits set by SRP *and* by absolute limit of 75% of port bandwidth capabilities
Pacing

- AV streams are paced using a common rate at all output ports
  - propose 8kHz pacing as used by IEC 61883 higher layers used by 1394
- Pacing is enforced at bridge output ports as well
- Spreads out traffic to reduce “bunching” at queues
- No increase in maximum latency
- Allows fixed maximum buffer size at each output port
  - No matter how many bridges in a path, the buffer will *never* overflow
Conclusion and discussion

• Timing synchronization, guaranteed low latency and guaranteed bandwidth are needed for CE-based streaming data
• Existing methods of carrying streaming data on bridged Ethernet networks either require management or fail to have guaranteed QoS
• Modest additions to bridges and DTE will meet all requirements
  – a proposed architecture has been examined by implementers and blessed as “virtually no cost”
  – the Devil’s in the details, however, so ...
• Please contribute!
Thank you!