NOKIA

Time Sensitive Networking: TSN als Erweiterung zu Ethernet für IIoT?

Experten-Roundtable: Next-Gen-Networks: Gezeitenwechsel?

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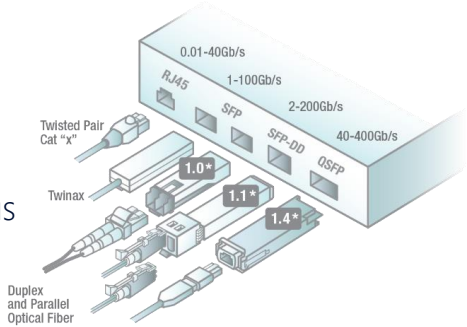
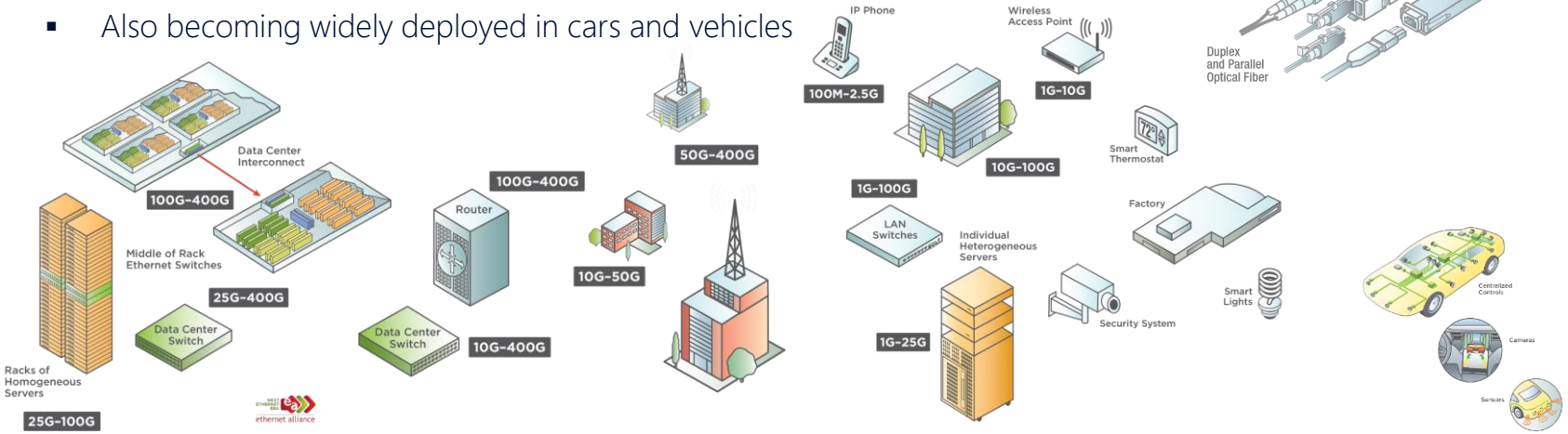
Nokia Standards, IEEE Standardization

What is Ethernet?

Ethernet is the most common type of local area network (LAN) technology

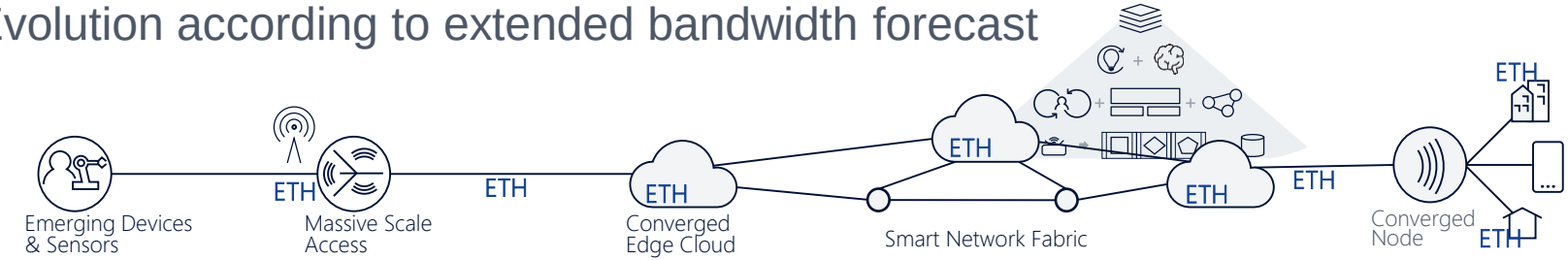
- Hardwired data communication connection through cables.
  - Twisted pair wires (1-pair, 2-pair, 4-pair (Cat5, Cat6, …), fiber
- Ethernet connects devices (end-stations) over up to several kilometers
  - Typically used in home, office or factory setting within the same building or campus
  - Also becoming widely deployed in cars and vehicles

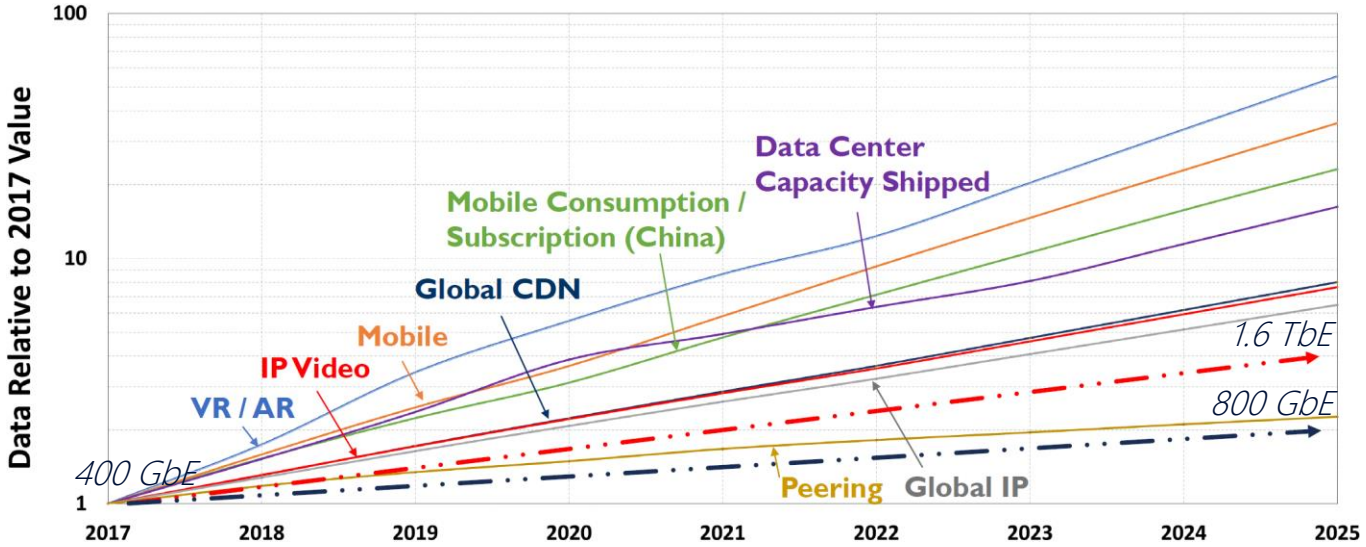




Ethernet copes with the growing communication demand

Evolution according to extended bandwidth forecast





Source: IEEE 802.3 NEA Ad hoc Ethernet Bandwidth Assessment, Part II, March 2020

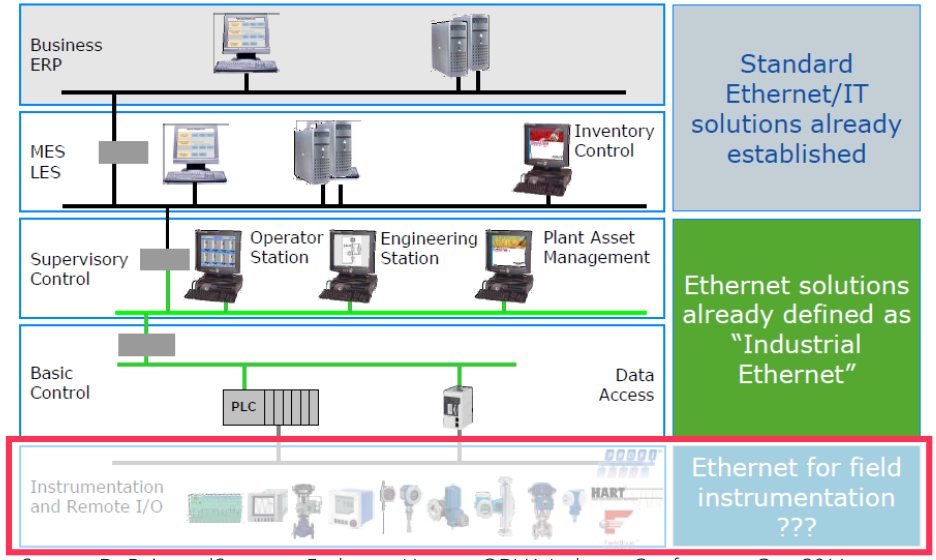
Single Pair Ethernet

A low-speed variant especially for IIoT

- Desire to converge on **one** network type
  - Ethernet in use where technically possible
  - Replace non-Ethernet fieldbuses to complete communications to the edge
    - Cable lengths > 1km
    - 1200 baud to hundreds of kbps
- Challenges: Combined reach & rate, special environments, cost of operation

The solution:

- IEEE 802.3cg – 10 Mb/s Single Pair (10SPE)
  - T1L: Point-to-point 1km full duplex PHY
  - T1S: Point-to-point 15m half duplex PHY
    - Optional full duplex
    - Optional half-duplex multidrop - return to CSMA/CD shared-medium networking
    - Optional physical layer collision avoidance (PLCA) to increase efficiency
  - Power over DataLine (PoDL) for up to 50W

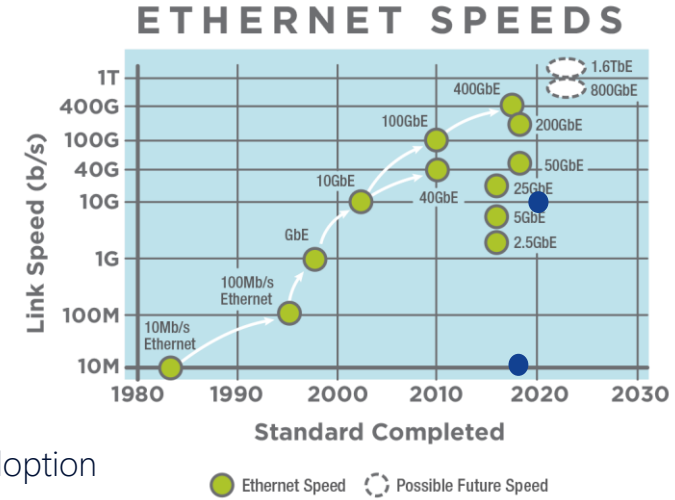


Source: Dr.RaimundSommer, Endress+ Hauser, ODVA Industry Conference, Oct. 2014.

- For automotive with higher speed (.. 10 Gbps):
  - IEEE 802.3ch w/ point-to-point, up to 15m reach

IEE 802.3 Ethernet

Pros & Cons



- Benefits:
  - Speed: 10 Mbps … 400 Gbps (…. 1.6 Tbps)
  - Stability: Low error rate < 10^{-11}
  - Security: Less interceptable than wireless transmissions
  - Economy: Best performance/price through widespread adoption
- Issues:
  - Accessibility: Each connection requires a dedicated cable and switch port
  - Mobility: Wires or fibers are not well suited to be moved around.
  - Cost: Cables and installation of cables could become expensive.
  - Scalability: Bridges add unpredictable transmission delays and packet losses
    => addressed by Time Sensitive Networking (TSN), see following slides.

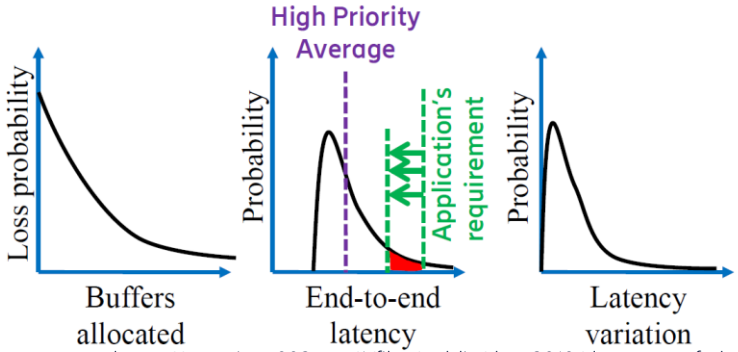
IEEE 802.1 Time Sensitive Networking (TSN)

Extensions to ‘best effort’ bridging to enable deterministic Ethernet networking

- Time synchronization for network nodes and hosts to better than 1 µs
- Resource reservation for critical data streams
- Extraordinarily low packet loss ratios, starting at 10^{-6} and extending to 10^{-10} or better, together with guaranteed end-to-end latency for a reserved flow.
- Convergence of critical data streams and other QoS classes (incl. best-effort) on a single network

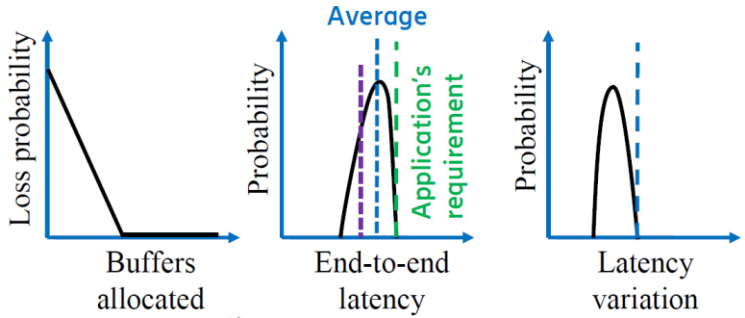
Traditional (best-effort) service

Losing packets due to exceeding latency



Deterministic service

The right packet at the right time



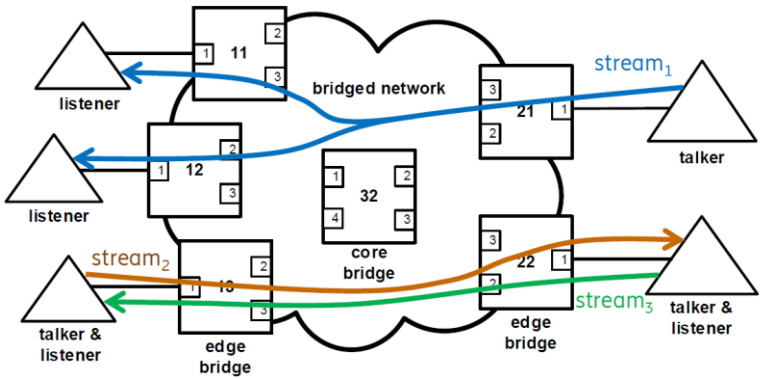
Picture source: https://www.ieee802.org/1/files/public/docs2018/detnet-tsn-farkas-tsn-basic-concepts-1118-v01.pdf

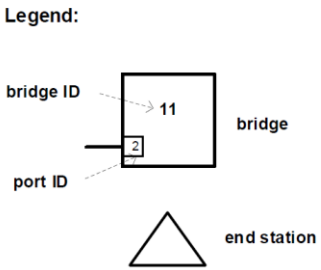
TSN basic concepts

Two types of devices involved: bridges and end-stations

TSN network architecture

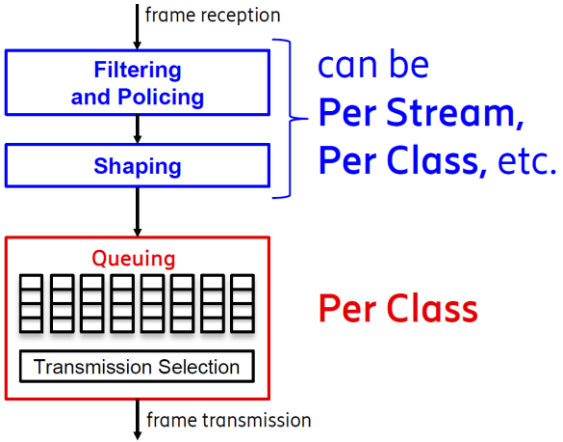
- Talker: The end station being source or producer of a stream
- Listener: The end station being the destination, the receiver, or the consumer of a stream
- Stream: A unidirectional flow of data from a Talker to one or more Listeners





TSN bridging

- Sophisticated filtering, policing, shaping, and queuing enable hard QoS in bridges.

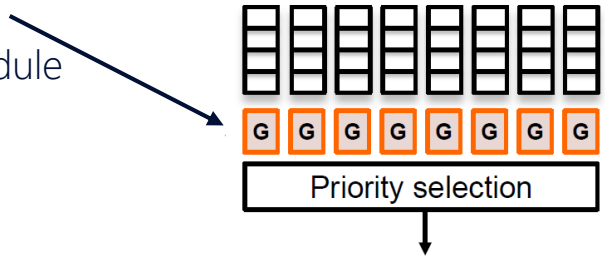


Picture source: https://www.ieee802.org/1/files/public/docs2018/detnet-tsn-farkas-tsn-basic-concepts-1118-v01.pdf

TSN in action, e.g. Scheduled Traffic (802.1Qbv)

Reduces latency variation for frames with known timing

- Time-based control and treatment of the bridge queues
- Time-gated queues
  - Gate (G): either open or Closed
- Periodically repeated time schedule
- Time synchronization is needed



Transmitted frames:
critical / non-critical

Gates for
non-critical traffic

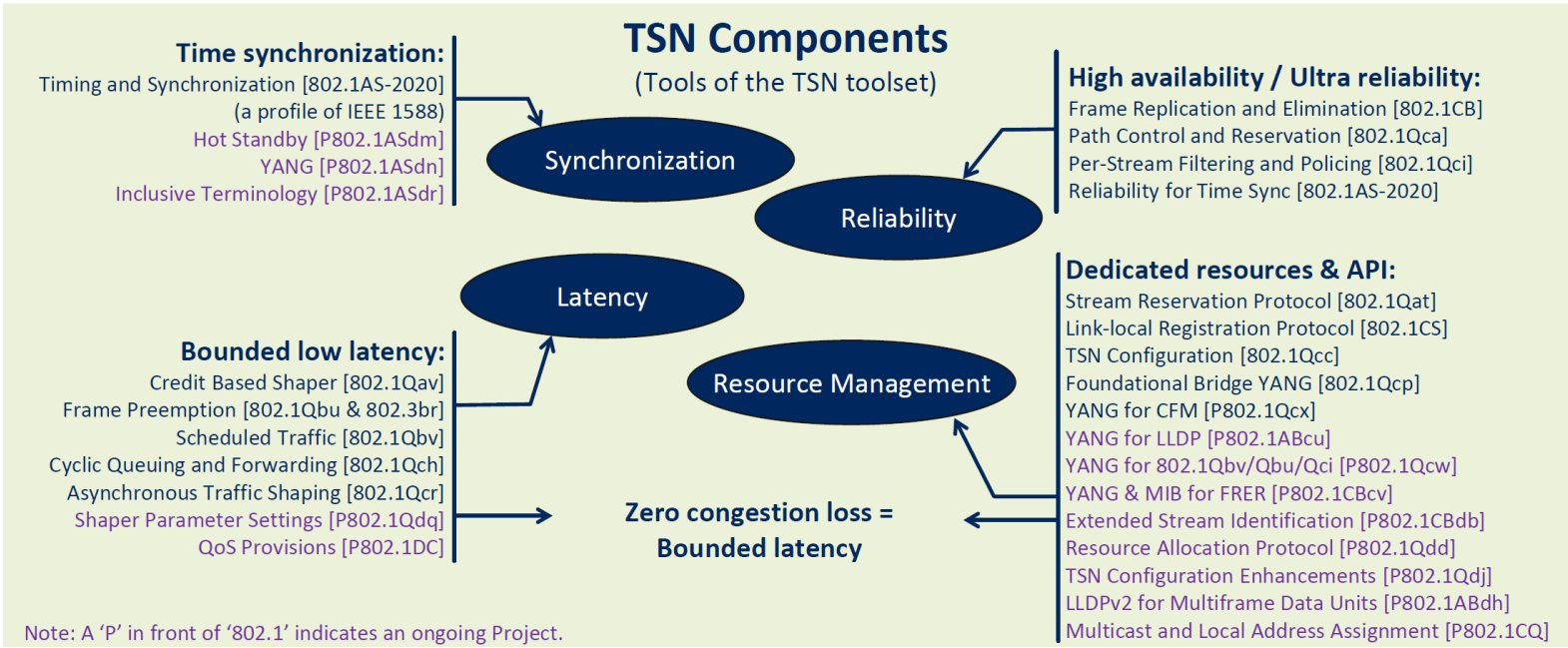
Note: To protect critical data transmission, gate of non-critical data can be closed in advance

Picture source: https://www.ieee802.org/1/files/public/docs2018/detnet-tsn-farkas-tsn-basic-concepts-1118-v01.pdf

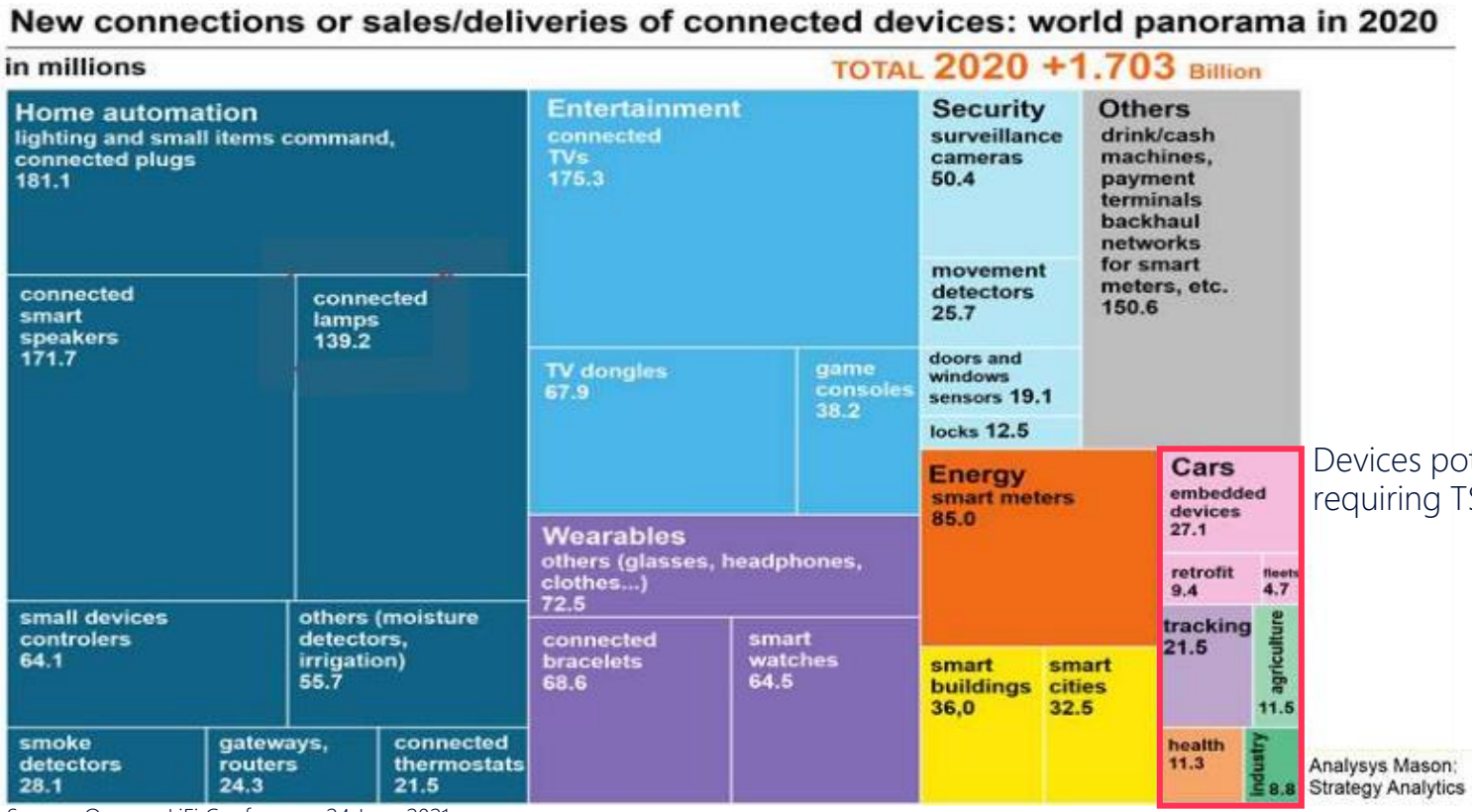
Time-Sensitive Networking (TSN) Profiles and Components

Profiles define selection and use of TSN tools (https://www.ieee802.org/1/tsn)

Audio Video Bridging [802.1BA/Revision]	Fronthaul [802.1CM/de]	Industrial Automation [IEC/IEEE 60802]	Automotive In-Vehicle [P802.1DG]	Service Provider [P802.1DF]	Aerospace Onboard [IEEE P802.1DP / SAE AS6675]



Which are the IoT devices requiring TSN?



Devices potentially requiring TSN

Source: Orange, LiFi Conference, 24 June 2021

Summary and conclusion

TSN enables deterministic Ethernet networking, but how often is it really needed?

- Ethernet is the prevalent (wired) network interface
  - All data transmitted over communication networks passes multiple times over Ethernet interfaces.
- Evolution of high-speed Ethernet copes with the Internet bandwidth explosion.
- But Single Pair Ethernet w/ Power over Data Lines may fertilize more the digital revolution of IIoT.
- TSN is an enhancement to Ethernet bridging allowing for deterministic network behavior avoiding packet loss and ensuring timely packet delivery in converged environments.
  - IEEE 802.1 developed a huge protocol toolset for TSN, and is still extending the capabilities.
- The predominant portion of IIoT might work without TSN support, but TSN is a key enabler for the convergence of all applications in one network.
- TSN makes Ethernet networks complex and puts high burdens on network management
  - Autoconfiguration still in its early infancy
- Is there need for TSN in the wide area networks?

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