

Extending Accurate Time Distribution and Timeliness Capabilities Over the Air to Enable Future Wireless Industrial Automation Systems

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- Proceeding of IEEE.

tags: Paper Study Communication Wi-Fi

Quick Summary

- Industrial Networks:
 - level categories: management level, cell level, field level
 - from (slow, large data) to (fast, small data)
 - realtime requirement categories: non-realtime, soft-realtime, hard-realtime
- Wireless standards in Industrial Networks:
 - 802.15.4 series(ZigBee)
 - Bluetooth
 - 802.11 series (Wi-Fi)
 - LPWAN(SigFox,LoRa)
 - Cellular network.(3G,4G,5G,NB-IOT...)
- IEEE 802.1 TSN:
 - handling time synchronization, control congestion, reliability communication.
 - mechanism:
 - Time synchronization
 - QoS control
 - Traffic identification
 - Network configurations
- TSN Challenge in Wireless communication
 - major different of wireless to wired communication
 - variable capacity, high per.
 - fundamental problem:
 - latency and jitter due to congestion
 - packet loss due to fading and collision
 - Wireless channel variety : capacity is dynamic
 - Large/Unreliable channel access latency:
 - LTE: grant protocol, random access
 - Wi-Fi: LBT protocol
 - Industrial requirements: ultra low latency and reliable communication
 - Interference and coex of different standards.

- New Approach To extend TSN to Wireless
 - Wireless Network Management by a single entity, devices implements a minimal set of features (CUC and CNC)
 - Time Synchronization for Wireless
 - 802.1as PTP over 802.11: TM/FTM(resolution to x00 us)
 - New Area for 5G.
 - Time-Aware Scheduling by synchronize to a common clock, control channel queue globally to control collision.(802.1Qbv)
 - Wireless link reliability:
 - power control to handle interference,
 - time-frequency resource management to optimize overall capacity and provide reliable transmission
 - spatial diversity and Beamforming to enhance link quality.
 - new waveform design: reduce out-band emissions, reduce overhead of short packets(typical in industrial traffic)
 - adaptive MCS selection with feedback csi.
 - redundant channels for better reliability.
- Next Generation Standard capability for TSN enhancement
 - 802.11ax :
 - scheduled access and multi-user ofdma,
 - 2M RU enhance link quality 8dB vs 11ac,
 - OFDMA-MU-diversity,
 - flexible GI(handling outdoor channel),
 - new 6G band to legacy standard interface-free and scheduled channel access.
 - Target wake time(TWT) for power saving and sub-grouping of devices for better resource management.
 - 5G URLLC:
 - low latency frame structure
 - slot time to 0.125ms
 - fast dl/ul switching and HARQ interval
 - self-contained data/ack in a sub-frame.
 - physical enhance: support LDPC and URLLC
 - low latency signaling: DMRS
 - Architecture enhancement: CRAN and SDN, edge computing
 - Industrial Wireless Network Applications categories:
 - Class A: supports current tech with enhanced features in 11ax/5G
 - Class B: Soft-time-sensitive(AR/VR,HMI,) and selective hard-time-sensitive(controller)
 - Class C: Hard realtime controllers with very low cycle times, ex. 802.11be EHT