NSF Engineering Research Center (ERC) for

Reconfigurable Manufacturing Systems (RMS)

Wireless extension of Ethernet POWERLINK based on the IEEE 802.11g WiFi

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Wireless networks in industrial communications

- Wireless networks PROs:
  - Cabling avoidance
  - Connection of mobile components
- It seems unrealistic that wireless networks will replace the traditional wired industrial networks (at least in the short/mid term), due to:
  - Reliability
  - Efficiency
  - Safety/Security
  - Costs,
  - etc…

KEY IDEA: an immediate employment of wireless networks for (possibly real-time) industrial communications is represented by the ***wireless extensions of (already deployed) wired networks!***

Wireless extension of wired networks

- Hybrid (wired/wireless) networks are an effective solution to the problem of *connecting few components (e.g. mobile components as robots, crane, etc…) to an already deployed wired communication system that can not be reached (easily and/or reliably) by means of a cable*

- Characteristics of hybrid networks:
  - The wireless segments have limited geographical extension (some tens of meters)
  - The number of wireless stations is limited
  - The “controller” is located on the wired segment
  - Limited amounts of data are exchanged (non-saturation conditon) on the wireless segments

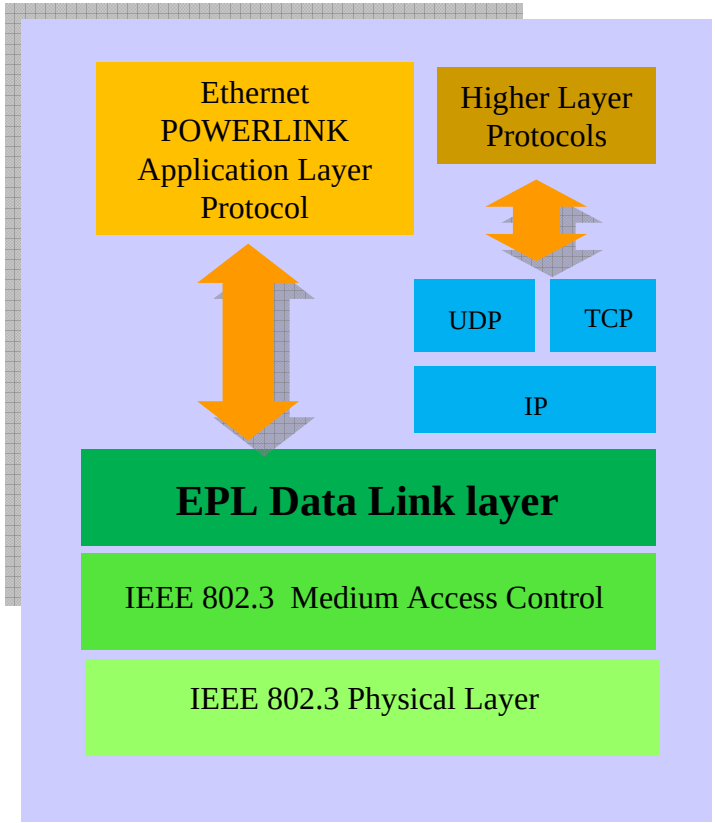
A case study: wireless extension of Ethernet POWERLINK based on the IEEE 802.11g WiFi

- Ethernet POWERLINK (EPL) is a popular RTE network
- Standardized by IEC 61784-2, Communication Profile Family #13, CP#1

- IEEE 802.11g is a well known wireless network
- High transmission speed (54 Mb/s)
- Frame prioritization (IEEE 802.11e)

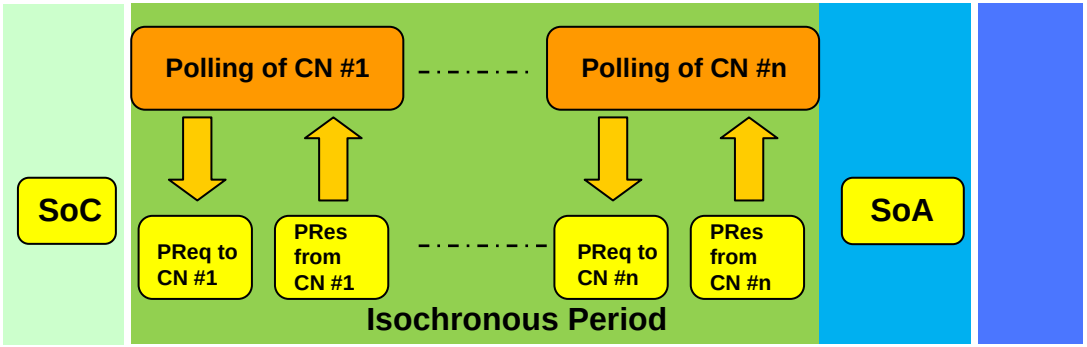
A case study: wireless extension of Ethernet POWERLINK based on the IEEE 802.11g WiFi

- Physical layer: 100 BASE-X, half duplex transmission
- Data Link layer protocol placed on top of the standard Ethernet MAC layer
- Application Layer based on the CANopen profile

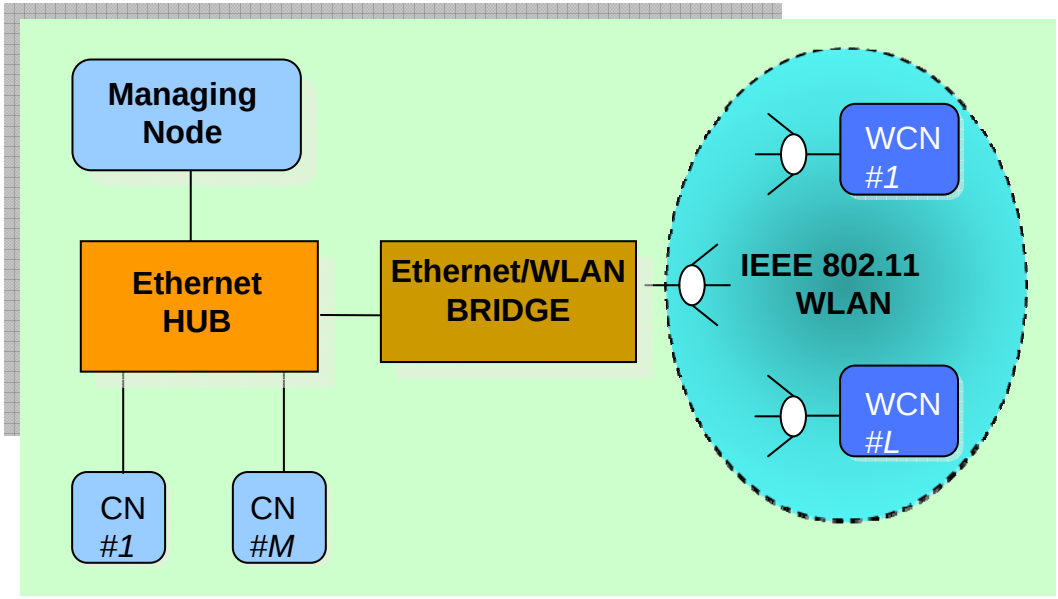


Some features on Ethernet POWERLINK

- EPL defines two types of station:
  - *Managing Node (MN)* (master device)
  - *Controlled Nodes (CNs)* (slaves devices)
- Hubs as connecting devices ensuring low latencies and limited jitter (but switches can be employed as well)
- Several configurations (tree, star, bus)
- TDMA realized by a *polling cycle* continuously repeated and timeouts



Wireless extension at the Data Link layer



- Interconnection achieved by means of an Ethernet/WiFi Bridge
- WCNs are directly included in the EPL cycle
- *The EPL Data Link layer protocol has to be implemented on the WCNs (availability of the EPL protocol source code)*
- EPL frames flow transparently across the bridge

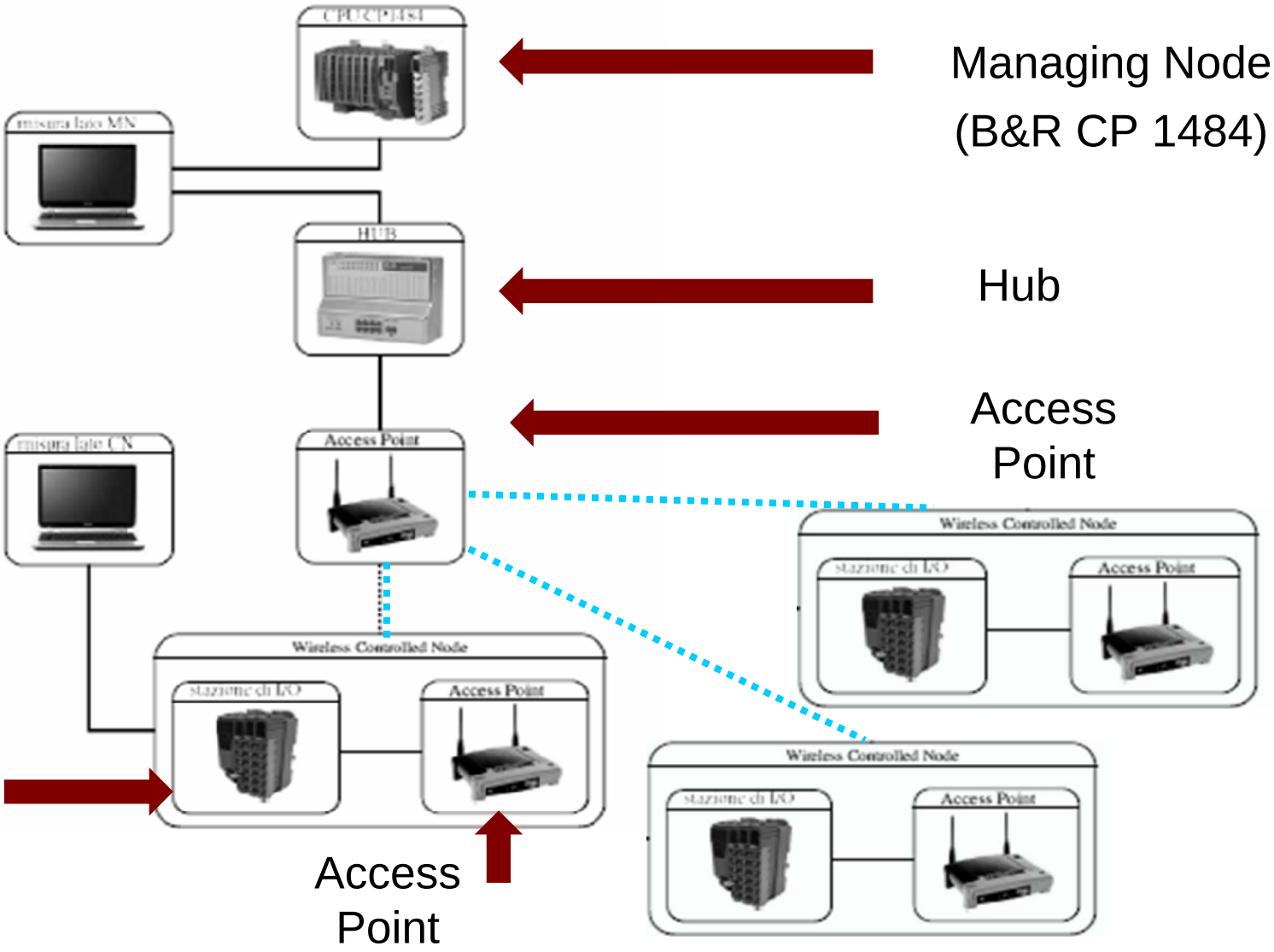
Theoretical and simulation analysis

- Parameter of interest: Isochronous Period
- Wireless connections are error prone
  - Fading (Gilbert-Elliot)
  - Spurious network traffic
- Non prioritized/prioritized frames

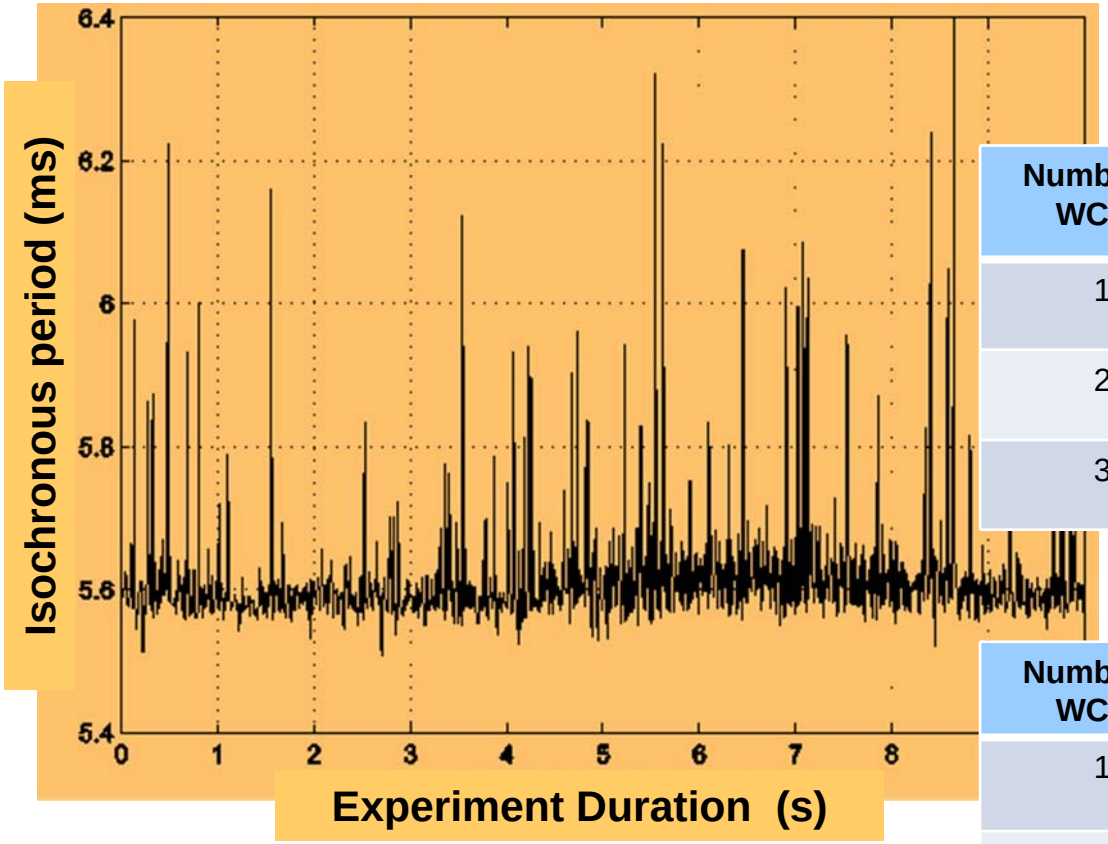
Nr. of WCNs	Mean (Ideal)	St. Dev. (Ideal)	Mean (20% Intf.)	St. Dev. (20% Intf.)
1	599	41.6	722	263.7
2	959	69.1	1189	431.1
3	1318	88.5	1654	557.4

Nr. of WCNs	Mean (Ideal)	St. Dev. (Ideal)	Mean (20% Intf.)	St. Dev. (20% Intf.)
1	545	10	602	133.6
2	867	40.5	954	197.3
3	1189	56.8	1316	253.8

Practical implementation: prototype network



Results



Simulation results

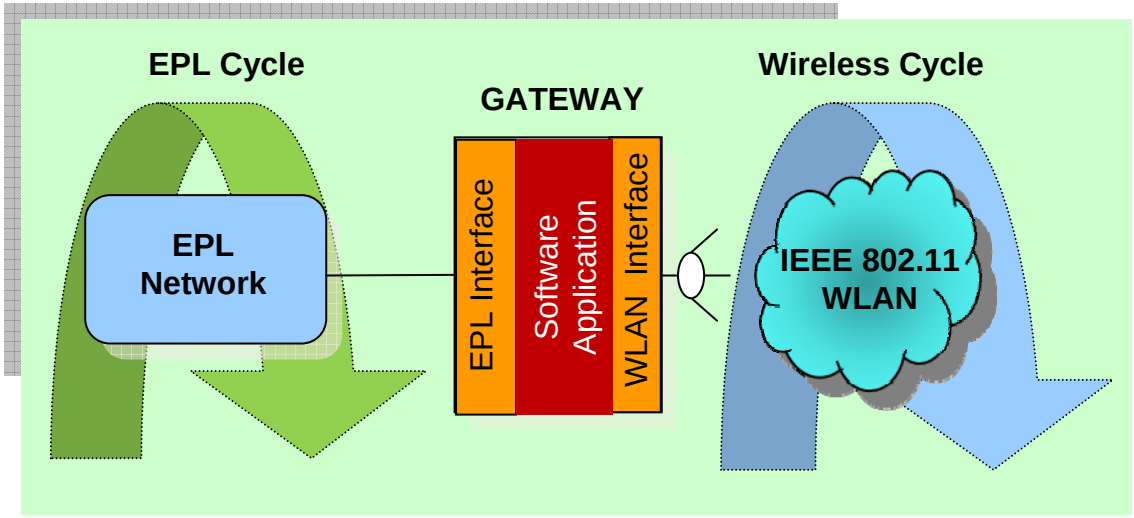
Number of WCNs	Mean Value	Std Deviation
1	0.599 ms	0.04 ms
2	0.959 ms	0.07 ms
3	1.318 ms	0.09 ms

Practical results

Number of WCNs	Mean Value	Std Deviation
1	2.15 ms	0.06 ms
2	3.88 ms	0.08 ms
3	5.62 ms	0.10 ms

Wireless extension at the Application layer

- Interconnection realized by means of a gateway that may be implemented either on the MN or in one CN
- WCNs are not directly included in the EPL cycle
- Two different cycles take place:
  - The EPL cycle handled by the MN that polls the wired CNs
  - The wireless cycle handled by the Gateway that queries the WCNs
- The wireless cycle may be either based on a polling procedure or driven by specific requests of data transmission to/from the WCNs



Considerations and future work

- Differences between theoretical/simulated analysis and practical implementation results (likely due to AP queues)
- Timeouts problems
- Proved feasibility of EPL wireless extension at the Data Link layer!
- Until now cycle time of 15-20 ms achievable (suitable for a considerable number of applications…)

- WCNs implemented on specific devices (PC or 802.11 single board)
- EPL extension at the Application layer (using 802.15.4, T-mote devices, gateway implemented on a PC with RT OS or on single board)

Thank you!