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

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November 4th, 2009

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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 condition) 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-Elliott)
- Spurious network traffic

Non prioritized/prioritized frames

<table>
<thead>
<tr>
<th>Nr. of WCNs</th>
<th>Mean (Ideal)</th>
<th>St. Dev. (Ideal)</th>
<th>Mean (20% Intf.)</th>
<th>St. Dev. (20% Intf.)</th>
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<tbody>
<tr>
<td>1</td>
<td>599</td>
<td>41.6</td>
<td>722</td>
<td>263.7</td>
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<td>2</td>
<td>959</td>
<td>69.1</td>
<td>1189</td>
<td>431.1</td>
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<td>3</td>
<td>1318</td>
<td>88.5</td>
<td>1654</td>
<td>557.4</td>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>545</td>
<td>10</td>
<td>602</td>
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<tr>
<td>2</td>
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<td>1189</td>
<td>56.8</td>
<td>1316</td>
<td>253.8</td>
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</tbody>
</table>
Practical implementation: prototype network

Managing Node (B&R CP 1484)

Hub

Access Point

Wireless Controlled Nodes

B&R I/O module

Access Point
Results

### Simulation results

<table>
<thead>
<tr>
<th>Number of WCNs</th>
<th>Mean Value</th>
<th>Std Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.599 ms</td>
<td>0.04 ms</td>
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<tr>
<td>2</td>
<td>0.959 ms</td>
<td>0.07 ms</td>
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<tr>
<td>3</td>
<td>1.318 ms</td>
<td>0.09 ms</td>
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### Practical results

<table>
<thead>
<tr>
<th>Number of WCNs</th>
<th>Mean Value</th>
<th>Std Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.15 ms</td>
<td>0.06 ms</td>
</tr>
<tr>
<td>2</td>
<td>3.88 ms</td>
<td>0.08 ms</td>
</tr>
<tr>
<td>3</td>
<td>5.62 ms</td>
<td>0.10 ms</td>
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</tbody>
</table>
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!