Techniques for Analyzing, Testing, Commissioning and Managing ZigBee Networks

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Wireless Communication Solutions

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Overview

• Presentation describes requirements and challenges for testing, analyzing, commissioning and managing
• Covers key aspects of the design and deployment lifecycles

Development Testing
- Application & profile development
- Small numbers of devices
- In the lab

System Verification
- Network analysis, performance analysis
- Full system of devices
- In the lab/field trials

Commissioning & Management
- Configure devices and network
- Verification, go/no-go conditions
- Full system of devices
- In the field, by installers & end-users

• Describe challenges, solutions and experiences with testing and analysis of ZigBee networks
Development Testing

Protocol Analysis
Development Testing with Protocol Analysis

- Main requirement here is verifying that:
  - The application was correctly implemented.
  - Protocol transactions are correct.
- Main tool used here is a protocol analyzer to “sniff” packets.
  - Commonly used tool.
  - Focus instead on what’s different about ZigBee for protocol analysis.
Development Testing with Protocol Analysis
Finding Packets of Interest

- ZigBee networks have:
  - Many devices.
  - Multi-hop meshed networking.
- Finding packets of interest can be a challenge. In any time interval:
  - Many devices could be transmitting.
  - A single packet could be transmitted multiple times on a multi-hop route.
Development Testing with Protocol Analysis
ZigBee Cluster Library and Verifying New Application Profiles

- You will be developing or extending your application profile.
  - Some may be based purely on public profiles and specifications.
  - Some may be proprietary, and some may be private.
- New ZigBee Cluster Library (ZCL) will speed up your development by allowing you to select clusters from libraries and re-use them for your own applications.
Development Testing with Protocol Analysis
ZigBee Cluster Library and Verifying New Application Profiles

Simple example from a test event

- “Identify” cluster is a new ZCL cluster that facilitates the identification of devices (e.g., to select a subset of devices for specific action).
- In the test event, a proposal was made to add additional commands to this cluster – command IDs 0x02 and 0x03.

New XML fragment (not currently in “Identify” cluster in the ZCL)

New command decoded...
Network Analysis
System Verification with Network Analysis

• Situation
  – Application has been developed.
  – Verified for a small handful of devices.

• Next step
  – Test a larger system more closely matching likely usage in your commercial solution.
    • More end devices.
    • Add routers to achieve multi-hop networking.
    • Devices distributed over larger area.
System Verification with Network Analysis

Distributed Analysis

- System will be:
  - Spread over a larger area.
  - Probably across different rooms, buildings or areas.

- Capturing packets
  - Single node will not pick up all the packets.
  - Multiple capture nodes will be required.

- Key requirements for distributed analysis:
  - Multiple capture nodes.
  - Clocks synchronized.
  - Capture nodes must be networked (e.g., via Ethernet or Wi-Fi).

- The result:
  - Single view of all packet exchanges for the entire network.
**System Verification with Network Analysis**

**Analyzing Network Formation**

- Analysis of network formation involves validating the following:
  - Did the device join the network?
  - How and where did the device join the network?
  - Is the network structure acceptable?

- The example below shows a tree being detected as devices join the network. A device joins the network by associating with a device already on the network.
System Verification with Network Analysis
Analyzing Mesh Connectivity

- ZigBee offers mesh networking.
  - Multi-hop connectivity
  - Devices separated by larger distances
  - Resiliency from temporary radio fading and interference
- Only effective if there are redundant paths through the network.
- The link quality indicator (LQI) is an indicator of this effectiveness.
  - Ensure sufficient redundant paths through the network for all devices.
  - Sections of the network should not be isolated (in an RF sense) from each other.
System Verification with Network Analysis
Tracing Packet Flows

• When packets do not reach their intended destination, it may be necessary to trace packet flows.
  – Which route did the packet take? Which routes failed? Why?

• This example shows a visual representation of such a trace.
System Verification with Network Analysis
Tracing Packet Flows

Cross-reference to protocol analyzer to obtain packet list to dig a little deeper.
System Verification with Network Analysis
Tracing Application Layer Messages

• Analysis of application layer messages encompasses:
  – What are the messages being sent between endpoints?
  – Are the right messages and values being sent?
• Example below shows active endpoints (red rectangles) for each device (blue circles).
System Verification with Network Analysis
Tracing Application Layer Messages

To analyze and troubleshoot further, cross-reference back to protocol analysis.
System Verification

Performance Analysis
System Verification with Performance Analysis

• Situation
  – Functional aspects examined.

• Next step
  – Validate that the system meets the application requirements.
  – Works correctly as part of the large system.
System Verification with Performance Analysis

Scenarios

• A “light” network of:
  – 20 sensors.
  – Collecting readings every five minutes.
  – Occasional data loss is acceptable.
• Less susceptible to performance issues.

• A “heavier” network of:
  – 300 sensors and actuators.
  – Sensors generate updates every five seconds.
  – Commands to actuators cannot be lost, but delays are acceptable.
  – Loss is unacceptable.
• This network is likely to be heavily loaded and could suffer from congestion. Furthermore, packet losses must be minimized, but some delay is acceptable.
System Verification with Performance Analysis

Performance Metrics

- **Key metrics**
  - End-to-end packet count/loss
  - End-to-end data rate/throughput
  - End-to-end delay
  - These describe the overall network performance.

- **Other metrics**
  - Per-hop data rate/throughput
  - Per-hop delay
  - Individual device (router) loading
System Verification with Performance Analysis

Network Design Considerations

• Goal of performance analysis
  – Specify network designs to meet the application’s performance requirements.

• Some basic guidelines are:
  – Avoid congestion & bottlenecks.
    • Physical layout or the use of star networks.
    • Reduce delay and packet losses.
  – Maximize redundant paths (meshed networking).
    • Alternative routes during short-term radio fading or interference.
    • Multiple routers are within (reliable) radio range.

• Create rules for network design and layout for installers to follow.
  – Don’t place near certain objects, for every X end device, have Y routers, etc.
System Verification with Performance Analysis

Obtaining Performance Measurements

- Measurements can be obtained by observing the packet exchanges between devices.
- Visual measurements can quickly highlight issues.
System Verification with Performance Analysis

Obtaining Performance Measurements

Numerical measurements can provide network-wide performance summaries.

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- Devices struggling to be heard by neighbors will have high retransmissions.
- End-to-end latency for all routes.
- Packet loss indicator.

All devices 04bf sent packets to (and the associated performance)
Commissioning & Management

Design, Configuration, Verification, Management
Commissioning & Management

• Situation
  – The system has been verified.

• Next steps
  – Setting up the end-user or professional installer for success.
  – Key objective is to ensure that the task of commissioning and managing a ZigBee system is relatively straightforward and easy, with appropriate tools.
Commissioning & Management
Key Considerations

- Application developers should consider network deployment and management requirements.
  - How will the system be commissioned?
  - How will success be determined?
  - What are the requirements for ongoing maintenance and management?
  - What tools are required?

- The solution must reflect specific requirements during installation & management and skills of installers, which are often different from developers or engineers.

- Scope includes:
  - System design and planning.
  - Simple and easy configuration and commissioning of devices.
  - Device and system verification.
  - Ongoing management of the system.
Prior to actual commissioning, a design/planning phase may take place for larger systems.

The tasks in this phase include:

- Dimensioning the system:
  - Quantities of each device type.
  - Cost estimation (especially for tenders).
- Ensure effective wireless connectivity:
  - With device and router placements.
  - Interference by and to other wireless technologies.
Simple & Easy Commissioning

- With a plan in place, installers (often electricians) will install devices according to the plan.

- The tasks include:
  - Device placement and configuration, including:
    - Channel selection, network ID and security information.
  - Tracking and logging of device information, including:
    - Matching serial numbers to specific devices.
  - Application bindings, grouping and settings.
    - Binding a light bulb to a switch, setting thermostat levels, etc.

- Much of the complexity of working with wireless infrastructure must be hidden from the installer/end-user.
Commissioning & Management
Device & System Verification

• Prior to completion:
  – Feedback on installation success and failure.
  – Ongoing monitoring and failure detection may be required for larger, more complex systems.
• The tasks in this phase include:
  – Operational
    • Device is active, device joins network.
  – Configuration
    • Correct binding and group settings.
  – Connectivity
    • Devices can reach each other.
  – Performance
    • Network and router performance meets requirements.
  – Alerts and logs
• Again, simple report/results are required, depending on the skills and knowledge of the installer
Commissioning & Management
Management & Maintenance

- Ongoing management and maintenance is often required to ensure operational efficiency, or to handle addition, replacement or reconfiguration of devices or the system.
- The tasks in this phase include:
  - Upgrade of devices
    - Over-the-air or wired upgrades
  - Device and asset tracking
    - Locationing systems
  - Device management
    - Add/remove/reconfig devices

- Unique and powerful features available on TI’s CC24xx product family that can aid in management and maintenance:
  - Over-the-air firmware download to simplify in-the-field upgrades
  - Automatic locationing of devices for applications requiring location information and simplify the installation and management task
Conclusion

• In this presentation, we have:
  – Examined requirements, challenges and techniques for testing, analyzing, commissioning and managing wireless sensor systems based on 802.15.4 and ZigBee.
  – Discussed requirements for development, system testing, field trials and deployment.

• For more information
  – Learning: http://www.daintree.net/learning/learning.htm
  – Product: http://www.daintree.net/products/products.htm
  – ZigBee: www.zigbee.org
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