Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Focused Use Cases and Possible Timeline of Dependable Wireless M2M and BAN]
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Abstract: [Body area networks (BAN) should be more dependable for major life-critical applications such as medicine, disaster, dependable sensing and controlling cars, buildings, smart grids, and smart city by extending BAN from human body to bodies of cars, buildings, and so on. That is so-called BAN of things like Internet of Things. While keeping advantages of IEEE 802.15.6, specifications of MAC and PHY may be revised to make it much more reliable, secure, fault-tolerant, robust against undesired factors. This slides may offer opportunity to discuss on use cases and applications of this standard.]

Purpose: [The discussion on use cases and applications will lead definition and requirement of current ongoing research and development on dependable wireless networks.]

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Use Cases and Possible Technologies for Dependable Wireless M2M and BAN

17th March, 2014 Beijing
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Agenda

1. Background and Demand of Dependable Wireless
2. Review of Previous Meetings
3. Definition of Dependability in Wireless Networks
4. Use Cases and Applications of Dependable Wireless
5. Theories and Technologies for Dependability
6. Related Activities
7. Action Plan
1. Background

- IG-DEP started July 2012 but has not discuss on major use cases and applications yet although definition of Dependability has been discussed.
- Discussion on use cases and applications we should cover in IG-DEP may lead definition and requirement common with and different from IEEE802.15.6 BAN standard.
- Applications Matrix has been useful for developing a categorisation scheme and analysing technical requirements – However, insufficient by itself for proposal design and evaluation
- ITU-R has covered M2M in SG11 and others.
- IEEE802.15 SG-SRU and 802.11 other SGs may have relationship

- Doc. IEEE802.15-12-0370-00-wng0: **Dependable Wireless M2M Network for Controlling - Applications for Cars, Energy, Medicine, Cities** –
- It was proposed to start either a **new IG on Dependable M2M** or a **IEEE802.15 TG6 amendment of BAN** in July. It could get about 40 supporting votes for this action.
- **It was asked Pat to postpone its opening** because a few could attend IR meeting in September due to several reasons.
- **Possible use cases and manners of** activities were discussed at sessions in Plenary in November 2012.
- **Two sessions of IG-DEP** in Orlando, March 2013 discussed with 12 attendees to focus on amendment of TG15.6.
- **Definition of dependability and its technical feasibility** were discussed in Hawaii, May 2013.
- **Use cases and applications** were discussed in Geneve, July 2013.
- **Focused use cases and action plan** were discussed in Dallas, Nov. 2013
Contents of IEEE802.15-13-0192-01-wng0 in March 2013

1. Recall of My Presentation in WNG Session in July 2012
2. Review of IEEE802.15.6 for Wireless BAN
3. Background for Amendment of IEEE802.15.6
4. Dependability of Wireless Networks
5. First Focus on Amendment of 15.6 for Dependable Medical BAN and Extend to BAN of Things
6. Possible Amendment of BAN
7. What to be documented
8. IEEE802.15.6 Deficiencies
9. Action Plan for TG6a(amendment of IEEE802.1.5.6)
10. Questions & comments
Discussion Items in Previous Meetings (1/2)

1. Whether to go for M2M or BAN amendment is still under consideration. Depends on participant interests.

2. How to detect and control effect of device hardware failure?
   – Hardware fault tolerance in devices.
   – How to attain protocol fault tolerance?

3. Dedicated band would solve interference issues.
   – Amount of band available will constrict usable applications.

4. Dependability means the device will certainly work for a specified period.
   – It may work longer, but dependability is not guaranteed anymore.

5. Car control electronics may be too sensitive for wireless acceptance, but auxiliary electronics like entertainment, etc. would greatly benefit from wireless dependable technologies.
   – The systems would be a one whole set however.

6. Mass market may offset additional cost of reconfigurable and reliable technology.
To pursue dependability in network may be possible to go beyond IEEE802.15 scope. Document (doc #440r0) on techniques for dependability at communications layers.

Approach by layers: Management layer at the side with hooks to other layers.

(1) Application Layer: Quote from Hawaii session: “Collect trending retransmissions and other info to prevent failures.”

(2) Link Layer:
- Quote from Hawaii session: “MAC layer error may be able to correct by adaptation to guarantee delay specification (e.g. to switch to fragmentation, change to lower coding rate, change back-off window, change number of retransmission attempts, cooperate with other MACs to create virtual MIMO, use L2R), rather than incur delay by going to Apps layer.”

(3) Physical Layer:
- Quote from Hawaii session: “MIMO and multipath are friends of dependability with PHY layer redundant links.”
- Quote from Hawaii session: “PHY layer can be adaptable to environment, by switching frequency particularly, if you are in a null.”
- Quote from Hawaii session: “PHY layer error may be able to correct by adaptation (switch to a better antenna) to guarantee delay specification rather than incur delay by going to Apps layer.”
3. Dependability in Wireless Networks

• Meanings of Dependability:
  – For us, “Dependability in network” means to guarantee lowest performance enough high in a sense of highly reliable, safe, secure, fault tolerant, robust services in any predictable and even unpredictable worse environments.

• Demand for Dependable Networks:
  – Need for **Highly Reliable, Robust Communications for Controlling**
  – Transition from Human centric communications to **Machine-to-Machine (M2M) communications**.
  – Highly reliable, safe, secure and robust communications for **M2M Controlling** is necessary.
  – **Integrated wired & wireless networks** provide dependable, green and ecological networks adaptable for environment.
4. Focused Use Cases and Applications

• Application Matrix Discussion: Participants are requested to send their envisioned use cases to start formulating the application matrix.

• So far Identified use cases are: Refer to Table ‘Use Cases’ in doc #412r2

• Use Cases
  – Medical
  – Car
  – Factory automation
  – Disaster prevention
  – Indoor positioning
  – Energy flow control
  – Building and smart city management
  – Public safety
  – Personal information space
  – Government information
Possible Use Cases of Dependable M2M and BAN for Sensing and Controlling

Collision Avoidance Using inter-vehicle and roadside networks
Collision Avoidance and safe driving by inter-vehicle networks
Road to car networks
Inter-vehicle networks
Car LAN & Wireless Harness
Inter-module wireless Networks
Factory Automation (FA)
Dependable Wireless Sensing Controlling for Manufacturing (CIM)

Dependable Wireless Networks for Transportation
Car Navigation & Collision Avoidance Radar

Wearable BAN
Implant BAN
Dependable Network among vital sensors, actuators, robots
UWB can solve such a problem that radio interferes a human body and medical equipments

Dependable BAN for Medical Healthcare
EEG, ECG, Blad Pressure Temperature
MRI images Etc.

Pacemaker with IAD
Capsule Endoscope
Dependable Network among vital sensors, actuators, robots

Silicon Base
MMIC (Flip Chip)
On Chip Antenna and Wireless Network in chio
Multi-layer BCB
Micor Machine Fablication
Dependable Wireless System Clock in Micro Circuit & Network in Devices

Ryuji Kohno(YNU, CWC, CWC-Nippon),
Jussi Haapola(CWC)
5. Theory and Technology for Dependable Network: Interdisciplinary Works between Controlling Theory and Communication Theory

1. A transceiver has to know the aim of controlling.
2. Controlling theory describe the action by mathematical form for the aim.
3. Conventional controlling theory does not care of transmission errors in a wireless channel but focus on stability of controlling.
4. Conventional communication theory or information theory does focus on transmission errors but does not care of different importance or priority of each information segment.

We need to combine Controlling Theory and Communication Theory for Dependable Wireless Controlling or M2M.
5.1 Research Subjects of Dependable Wireless

(1) Although conventional controlling theory does not care of errors in a link or a channel, a new controlling theory will be established in a case of assuming channel errors in a controlling link or network. A new communication theory for M2M controlling should be established to achieve much more reliable, secure, robust against errors, or dependable connection.

(2) Common theories and algorithms between controlling and communication theories will be established. For instance, Levinson-Darvin algorithm in linear prediction has commonality with Barlecamp-Massy algorithm of coding theory.

(3) Dependable wireless M2M may promote a new global trend of R&D and business in wide variety of industries, car, energy, communications, finance, construction, medicine in a world.
5.2 Common Themes and Algorithms between Controlling and Communication Theories

Communication Theory ↔ Control Theory

- Encryption Theory
- Coding Theory
- Complexity Theory
- Computing Theory
- Game Theory

- Information Theory
- Fast Calculation Algorithm
- Stochastic Theory
- Booph-Barger Algorithm

- Fault Tolerance
- Linear Programming, Newton Algorithm
- System Engineering
- Enhanced Study Algorithm

- Stability Analysis
- Fault Check and Alarm
- Algorithm Theory
- Viterbi ML Algorithm

- Hash Function
- Entropy
- NP Complete
- Linear Programming, Newton Algorithm

- Channel Coding ARQ
- Stabilty Analysis
- Revinson-Daubin Algorithm
- Karman Filter
- Wiener Filter

- Digital Signal Processing
- Adaptive Filter
- LMS, RLS, Algorithm

- System Engineering
- Enhanced Study Algorithm
- Booph-Barger Algorithm
5.3 Basic Technical Requirements

- After defining dependability in network, we need to find reasonable technologies to satisfy requirements.
- **Application Layers:**
  - Information Security: Encryption and Authentication
- **Network Layers:**
  - Redundant Routing: Parallel, Relay or Multi-hop, Network Coding etc.
- **Data Link & MAC Layers:**
  - Non-opportunistic and reliable, secure MAC
- **Physical Layers:**
  - Diversity technologies in time, frequency and space domains
  - Channel coding for error-controlling, Hybrid ARQ, Space-Time Coding etc.
5.4 PHY Technologies for Dependable Wireless

1. Spread Spectrum (CDMA, Radar)
2. Adaptive Array Antenna (Smart Antenna, MIMO, Space-Time Coding, Collaborating Beamforming)
3. Diversity (Space, Time, and Frequency Domains)
4. Multi-band, Multi-Carrier (OFDM), Multi-Code
5. Coding (Turbo Coding and Decoding, LDPC, Space-Time Coding, Network Coding)
7. Cognitive Radio & Network
8. Ultra WideBand (UWB) Radio
9. Collaborative Communications and Sensing
5.5 Physical Layer Technologies Satisfying Multiple Demands for Dependable M2M and BAN

1. **Countermeasure techniques against fading Interference from other systems in a body area**
   - Equalization, Diversity, Coding, Antenna etc.

2. **Positioning • Ranging = Position recognition in Implanted Devices**
   - Radar, Navigation, Roaming

3. **Awareness and Control = Inside body sensing**
   - Observation of environment, Sensor, Adaptive control

4. **Security = Authentication • Privacy for vital**
   - Charge information, Privacy protection, terror measure

5. **Reconfigure = Changing operation • Fault searching**
   - Changing to new technology, Fault maintenance

6. **Antenna and Diversity**
   - Securing of good wireless communication environment

7. **Low power consumption = Long operable time**
   - Implementation of low power consumption and high quality

**Spread Spectrum & UWB Technology**

**Array Antenna, STC & MIMO Technology**

**Software Defined Radio (SDR) and Cognitive Radio Technology**

Ryuji Kohno(YNU, CWC, CWC-Nippon),
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5.6 Communication Technologies in each Layer for Dependable M2M and BAN

<table>
<thead>
<tr>
<th>Layer</th>
<th>Control mechanisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application layer</td>
<td>Control algorithm</td>
</tr>
<tr>
<td>Network (NWK) layer</td>
<td>Scheduling (packet order control)</td>
</tr>
<tr>
<td></td>
<td>Routing (route control)</td>
</tr>
<tr>
<td>Medium access control (MAC) layer</td>
<td>Time slot control (TDMA)</td>
</tr>
<tr>
<td></td>
<td>Frequency control (FDMA)</td>
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<tr>
<td></td>
<td>Contention window control (CSMA)</td>
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<tr>
<td>Physical (PHY) layer</td>
<td>Transmit power control</td>
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<tr>
<td></td>
<td>Modulation level control</td>
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<td></td>
<td>Coding rate control</td>
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</tbody>
</table>
5.7 Higher Layers Technologies for Dependable M2M and BAN

1. **Contention Free Protocol in MAC** (TDMA, Polling, Hybrid CFP & CAP etc)

2. **ARQ and Hybrid ARQ in Data Link** (Type I, II) combination of transmission and storage (buffering)

3. **Parallel Routing** (Risk Diversity) and **Network Coding** in network architecture

4. **Fault Tolerant Network** (Redundant Link and Parallel Hopping) and **Cognitive Networking**

5. **Encryption and Authentication in Application Layer** (AES, Camellia, Secret Sharing)
5.8 Cross Layer & Multi-Layer Optimization for Dependable M2M and BAN

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Layer</td>
<td>Cognitive, Reconfigurable, Adaptive, Robust Radio, Error-Controlling Coding, Space-Time Diversity, Equalization, Coded Modulation</td>
</tr>
<tr>
<td>Device/ Electronics Layer</td>
<td>Tamper Free Hardware, Robust Packaging, SoC, SOP, On-chip CODEC for channel Coding and Encryption</td>
</tr>
<tr>
<td>Data Link &amp; MAC Layer</td>
<td>Priority Access Control, Fault Tolerant Routing, ARQ, Hybrid ARQ, Distributed Resource Management</td>
</tr>
<tr>
<td>Application Layer</td>
<td>Information Security (Encryption and Authentication, User Friendly Interface)</td>
</tr>
</tbody>
</table>

Dependable Wireless with Less Power Consumption & Robustness

Join Optimization of Multi Layers

Ryuji Kohno (YNU, CWC, CWC-Nippon), Jussi Haapola (CWC)
M2M Controlling Communication Different from Usual Human-Base Communication

Transceiver has no need/intelligence to understand the meaning of the application in a usual Human-base communications.
M2M Controlling Communication Different from Usual Human-base Communication

Dependable Wireless M2M communications for controlling needs intelligence to understand the aim and the meaning of the application between Source and Destination.

Cognitive Radio or Beyond Cognitive Radio
Establishment of IEICE Study Group & Committee on Dependable Wireless

IEICE EES Society, May 2010

Aim of This Study Group

• Promote R&D and business in an interdisciplinary field between controlling and communications.
• Create new ICT theories and technologies for dependable wireless not assuming intelligence of nodes unlike human communications in an usual communications.
• Create new controlling theories and technologies for dependable control assuming errors in M2M and controlling network.
• Promote researching activities in multi-disciplinary fields among fault tolerance, information security, artificial intelligence, and related fields around communication and controlling theories.
• Promote business activities in wide variety of industries such as medical healthcare, transportation, smart grid of energy, disaster prevention, public safety, emergency rescue, factory automation, building construction etc.
Discussion

Scope of project:

• Address PHY and MAC layer functionality
• Possibility to create management plane on the side of PHY and MAC layers
• Enabling adaptive behaviour in 802.15 PHY and MAC layers
• Enable hub to hub communications
• PHY layer additions?
• ETSI Smart Ban project status
6. Procedure of Promotion to Next Steps

• We tried to proceed establishing IG, SG, and TG on Wireless Dependable M2M Network since the plenary session of July 2012. However, due to some restriction procedure was not speeded up.

• There are two major approaches to procedure IG to SG and TG.

(1) focus on amendment of BAN 802.15.6

(2) focus on different PHY and MAC for dependable M2M

• An amendment of IEEE802.15.6 must be more realistic while keeping advantages of the BAN standard as IEEE802.15.6a (?)
7. Possible Time Line

- IG $\rightarrow$ WG $\rightarrow$ SG $\rightarrow$ TG $\rightarrow$ Standard
- Technical Requirement
- 5C and PAR
- Proposals
- Down selection
- Letter Ballots
- Sponsor Ballots
- Rev Com Approval
Development process

Amendment of 802.15.6
New use cases of dependable M2M

Ryuji Kohno(YNU, CWC, CWC-Nippon),
Jussi Haapola(CWC)
Document structure

• Table of contents
• Use Cases & Applications, categorized
  – Parameters
  – Free text description
  – CFA slide extracts
• Acknowledgements
Contributions

• Not all applications may be comprehensively described but major applications must be covered.
• If you can offer further details, either updated parameters or free text, please contribute
• Send content contributions to
• Jussi Haapola <jussi.haapola@ee.oulu.fi> and Ryuji Kohno <kohno@ynu.ac.jp>
Reference documents

• Applications Summary Document of IEEE802.15.6 BAN
  – 15-08-0407-00-0006-tg6-applications-summary.doc
• TG6 Applications Matrix
  – 15-08-0406-00-0006-tg6-applications-matrix.xls
• IG-DEP kick-off documents
  – IEEE802.15-12-0370-00-wng0 in July 2012
  – IEEE802.15-13-0192-01-wng0 in March 2013
• IG-DEP agenda documents
  – Closing Minutes IEEE802.15-13-0454-00-0dep in July 2013
  – Dependable Tech. IEEE802.15-13-0440-00-0dep in July 2013
  – Use case IEEE802.15-13-0416-00-0dep in July 2013
  – Smart BAN IEEE802.15-13-0415-00-0dep in Sept. 2013
  – Focused Use Cases & Timeline IEEE802.15-13-0691-00-wng0 in Nov. 2013
  – Dependability-Tech.-at-communications-layers IEEE802.15-13-0440-00-0dep