

# Networking and Communications Research Area: Achieved results

2012-2015

# General Focus

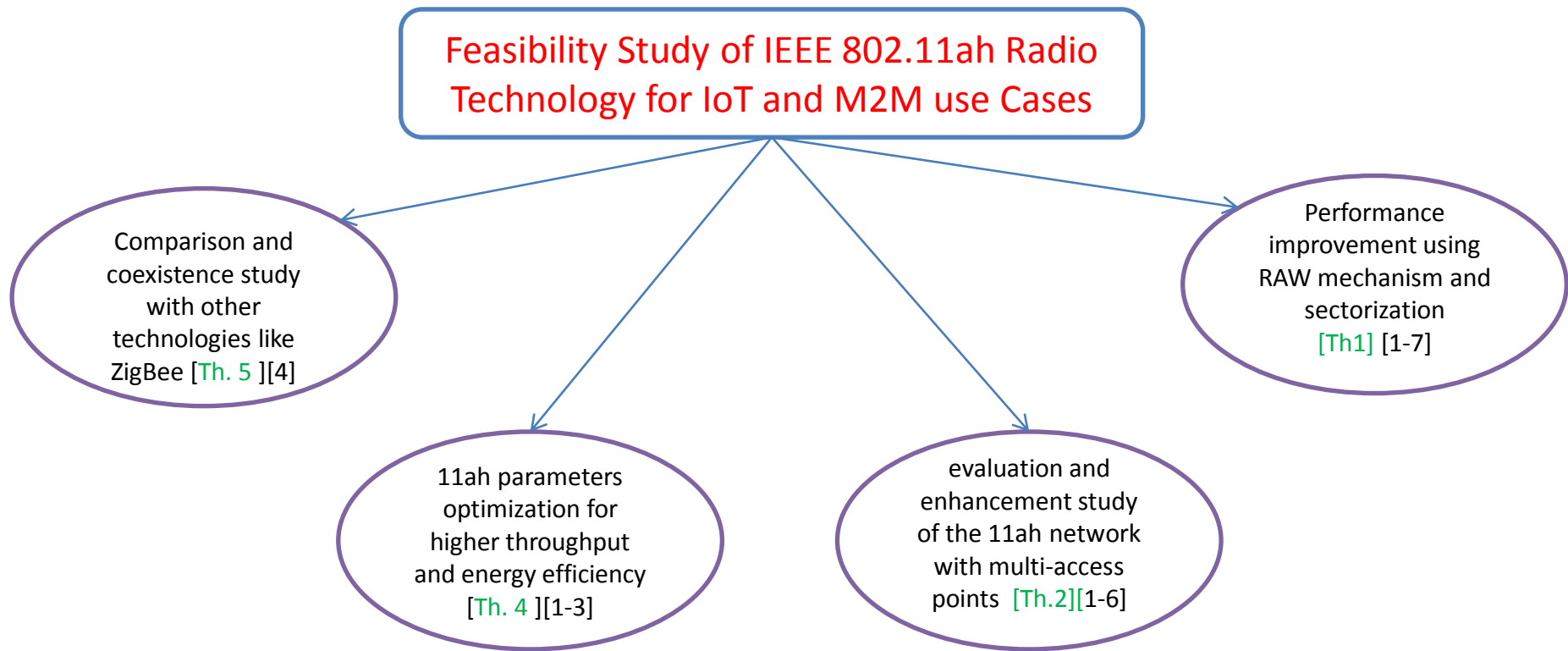
**Develop new as well as enhancing the existing radio communications and networking technologies to meet the challenges of massive IoT/MTC deployments**

**Enhance the basic wireless connectivity and networking layers to handle the expected large numbers of coexisting devices in the IoT networks**

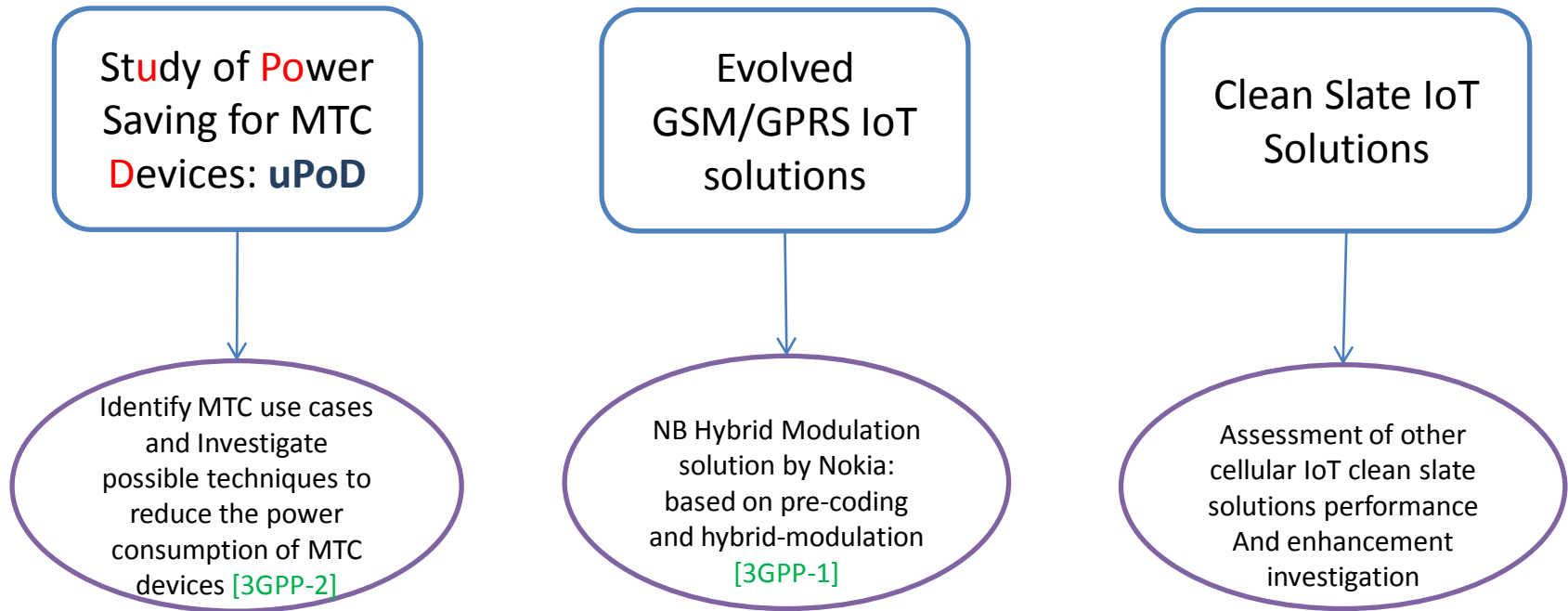
## **Considered Technologies**

- IEEE 802.11ah radio technology
- GERAN: GSM/GRPS radio connectivity
- 3GPP: Evolved GSM and Clean slate

# IEEE 802.11ah study: main achievements



# Cellular IoT study



# Standardization contributions

- The research in this task strongly contributes to 3GPP and IEEE standardization, primarily through industrial partners (RENESAS, NOKIA)

## Selection of IEEE and 3 GPP Std. contributions<sup>1</sup>

Year	Authors (IoT members in bold)	Title	Number	Type (draft, RFC, etc)	Forum (IETF, 3GPP, etc)
2012	Timo Koskela Tapani Westman Juho Pirskanen Anna Pantelidou (RMC)	Wi-Fi Offloading Considerations	IEEE 802.11-11/1515r1	draft	IEEE 802.11ah
2012	Anna Pantelidou Juho Pirskanen Timo Koskela	On the Suitability of Repetition for 802.11ah	IEEE 802.11-12/0101r0	draft	IEEE 802.11ah
2012	Anna Pantelidou Tapani, Westman, Juho Pirskanen, Timo Koskela (RMC)	Power Saving Possibilities for Networks Supporting a Large number of STAs	IEEE 802.11-12/0028r1	draft	IEEE 802.11ah
2014	Juergen Hofmann, Miikka Taponen, Petri Grönberg, Khairul Hasan, Juha Hartikainen, Hartmut Wilhelm	On Evaluation of Power Consumption of different MS tasks	GP-140291	Discussion paper	3GPP TSG GERAN

**3GPP-1** GP-140583, “Narrow Band Hybrid Modulation for Cellular IoT”, source Nokia Networks, 3GPP TSG GERAN#63

**3GPP-2** GP-140291 , “On Evaluation of Power Consumption of different MS tasks”,source Nokia Networks, 3GPP TSG GERAN#63

<sup>1</sup>Full list at: <https://wiki.helsinki.fi/display/iotproject/Standardization>

# Academic contributions

- Large number of high-impact scientific publications and MSc. thesis have been finalized in cooperation with Ericsson and Renesas

## MSc thesis

- Th. 1** Muhammad Qutab-ud-din Enhancements and challenges in IEEE 802.11ah- A sub-Gigahertz WI-FI for IoT Applications M. Sc. Thesis, Tampere University of Technology, 2015.
- Th. 2** Nader Daneshfar, Performance Enhancement Mechanisms of IEEE 802.11ah Machine Communication System. M. Sc. Thesis, Tampere University of Technology, 2015.
- Th. 3** Alessia Pantano, Energy harvesting schemes for radio technologies used in IoT: overview and suitability studies, M. Sc. Thesis, Tampere University of Technology, 2015.
- Th. 4** Orod Raeesi, System-level performance analysis and optimization of IEEE 802.11ah - The new sub-1 GHz Wi-Fi, M. Sc. Thesis, Tampere University of Technology, Finland, 2013.
- Th. 5** Behnam Badihi Olyaei, Modeling, performance evaluation and suitability study of ZigBee technology for Machine-to-Machine Communications Applications, M. Sc. Thesis, Tampere University of Technology, Finland, 2013.

# Academic contributions

1. M. Qutab-ud-din, A. Hazmi, B. Badihi, A. Larmo, J. Torsner and M. Valkama “ Performance Analysis of IoT-Enabling IEEE 802.11ah Technology and its RAW Mechanism with Non-Cross Slot Boundary Holding Schemes,” *IEEE WoWMoM 2015*, Boston, USA, June 14-17, 2015.
2. O. Raeesi, J. Pirskanen, A. Hazmi, T. Jukka, and M. Valkama., ”Performance Enhancement and Evaluation of IEEE 802.11ah Multi-Access Point Network Using Restricted Access Window Mechanism,” *IEEE DCOSS*. pp.287-293, May 2014.
3. O. Raeesi, J. Pirskanen, A. Hazmi, T. Levanen, and M. Valkama,”Performance evaluation of IEEE 802.11ah and its restricted access window mechanism,” *IEEE ICC*, Sydney, Australia, June 10-14, 2014.
4. B. Badihi, J. Pirskanen, O. Raeesi, A. Hazmi, M. Valkama, “Performance comparison between slotted IEEE 802.15.4 and IEEE 802.11ah in IoT based applications,” *IEEE WiMob*, Lyon, France, Oct. 7-9, 2013.
5. A. Hazmi, J. Rinne, and M. Valkama, “Feasibility study of IEEE 802.11ah radio technology for IoT and M2M use cases,” *IEEE Globecom Workshops*, pp.1687-1692, Anaheim, CA, USA, Dec. 3-7, 2012.
6. M. Qutab-ud-din, A. Hazmi, L. Felipe Del Carpio, A. Gökceoglu , B. Badihi, P. Amin, A. Larmo, M. Valkama “ Duty Cycle Challenges of IEEE 802.11ah Networks in M2M and IoT Applications” submitted to IEEE ICC 2016 SAC Internet of Things, 2016.
7. M. Qutab-ud-din, A. Hazmi, B. Badihi, F. del Carpio, P. Amin, A. Larmo, J. Torsner, M. Valkama“ IEEE 802.11ah: Analysis and Evaluation of Essential MAC Features in IoT Network,” submitted to *IEEE Internet of Things 2015*.
8. A. Ometov, D. Nader, A. Hazmi S. Andreev, F. Del Caprio, P. Amin, J. Torsner, Y. Koucheryavy, M. Valkama“ Analyzing Traffic Dynamics of IEEE 802.11ah Technology for Massive MTC Deployments,” submitted to *IEEE Internet of Things 2015*