Analytical Approaches for Short-range Wireless Technologies Evaluation

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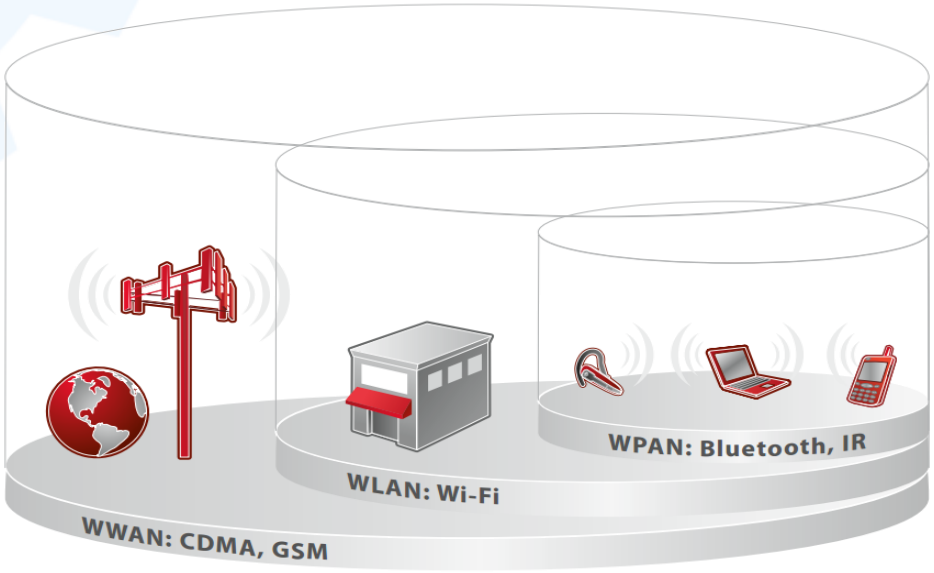
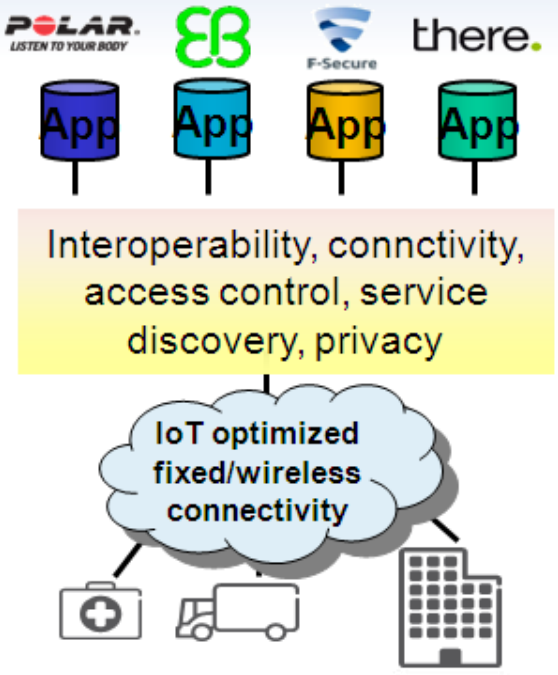
Random Multiple Access for Machine-type Communications

- Finnish Strategic Research Agenda
  - IoT as a major trend up to 2017

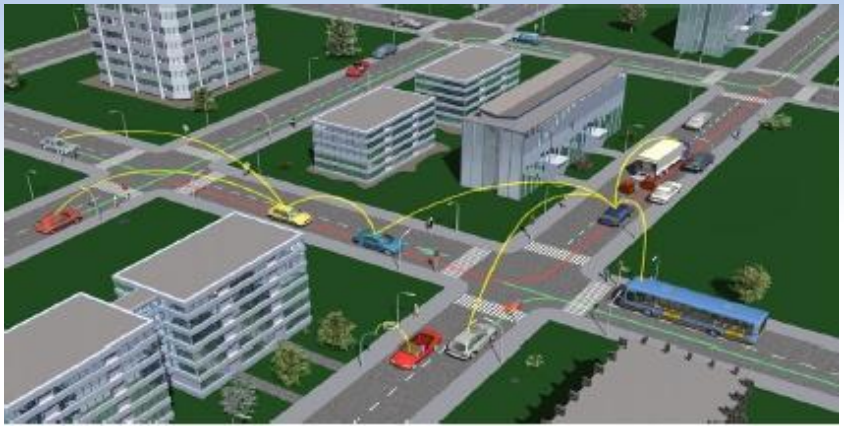




[Approach:] Mitigate technology fragmentation by ***reusing existing deployments***

Major use cases for IoT SRA

1. Mobile healthcare

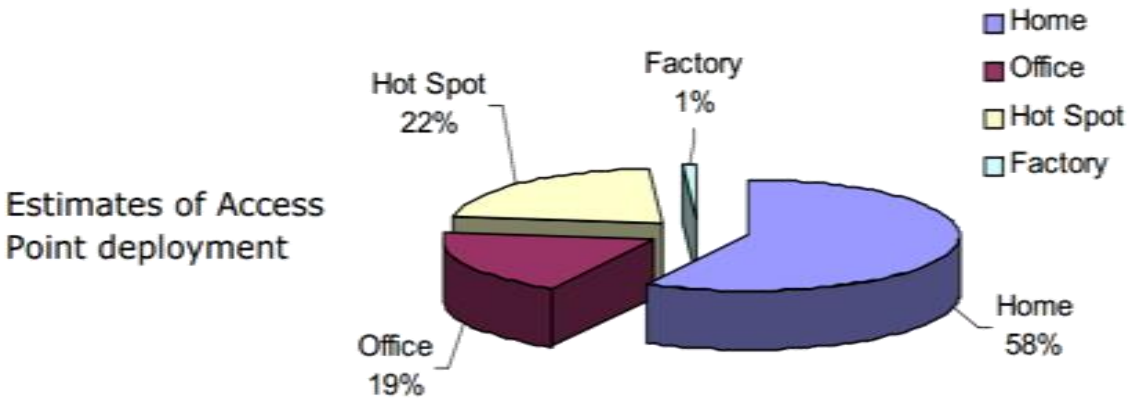


2. Road Security

3. Smart Grid

Focus on IEEE 802.11

- Wi-Fi – ***de-facto*** technology for WLANs
- Expected to ***minimize time-to-market*** for various MTC applications
- ***Assessing*** their ***performance*** is important



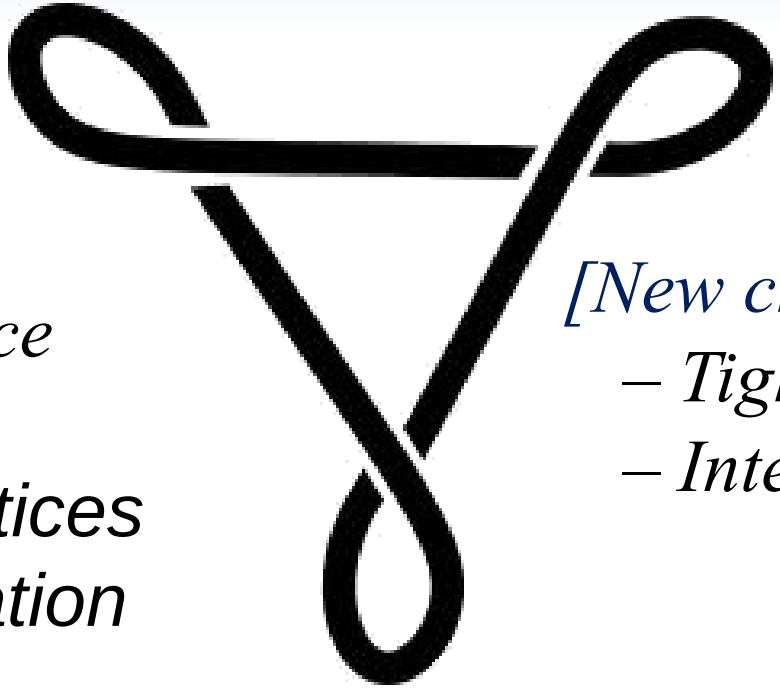
The major growth in access point deployment is in the home and in **urban hotspots**

***N. Hunn, "Using 802.11 for M2M", http://www.m2mforum.com/2006/eng/images/stories/hunnezurio.pdf**

Harmonization of approaches is proposed

Measurements

Analysis



- *Model convergence*
- *Best practices consideration*

[New challenges:]

– Tight battery budget

– Integrated services

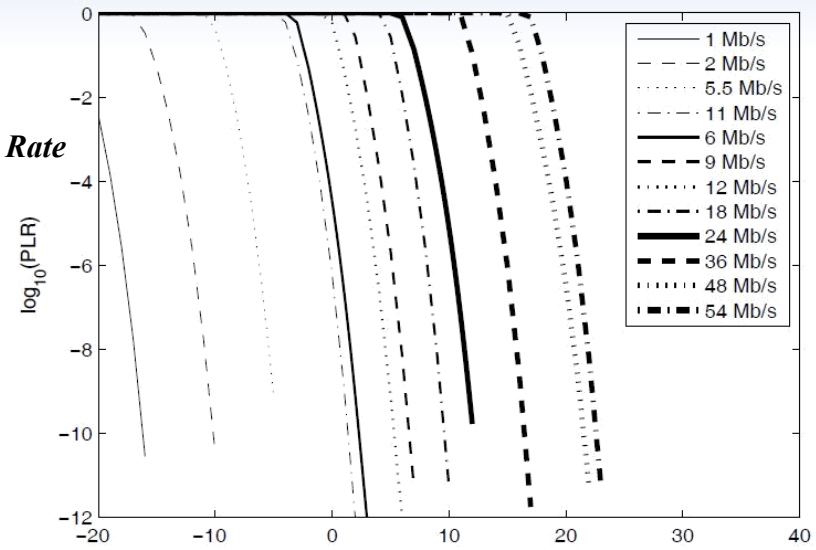
Simulation

Measurements

- IEEE 802.11 test bench development

*Extending approach
by D. Malone et al.

** K. D. Huang, D. Malone, and K. R. Duffy, "The 802.11g 11 Mb/s Rate is More Robust than 6 Mb/s", in IEEE Transactions on Wireless Communications, 2011.*



Open-source driver: ath9k

— Manual rate control

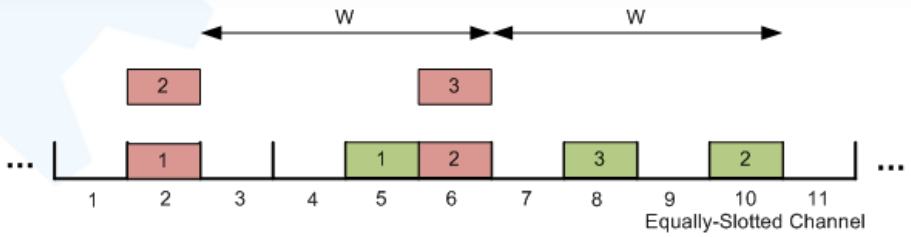
— No retries (genuine statistics)

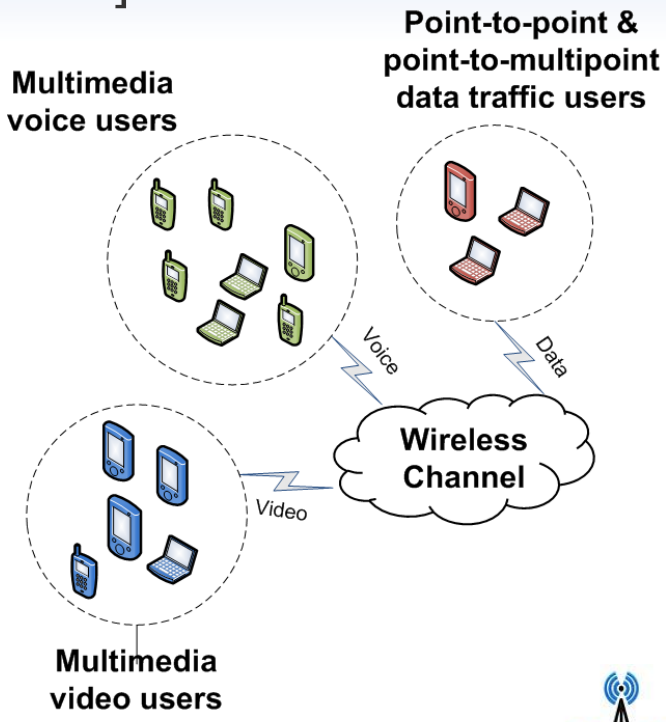
[New:] Applicable for emerging 802.11 releases (n, 2012, ac)
More detailed data collected (PET, queue statistics, etc.)

Analysis (1). Heterogeneous traffic

- Reusing and adapting past models

*Known from 1970th [Abramson], [Kleinrok]





Objectives:

- Quality of Service extensions
- Different channel access probabilities for different traffic classes
- Internal collision resolution

** S. Andreev, Y. Koucheryavy, L. Sousa, "Calculation of Transmission Probability in Heterogeneous Ad Hoc Networks" in Proc. of Baltic Congress on Future Internet Communications, 2011*

Analysis (2). Extended model. Battery budget and realistic packet loss

- Internet-of-Things use case
  - Tight batteries (rechargeable ?)
  - Delay-tolerant traffic

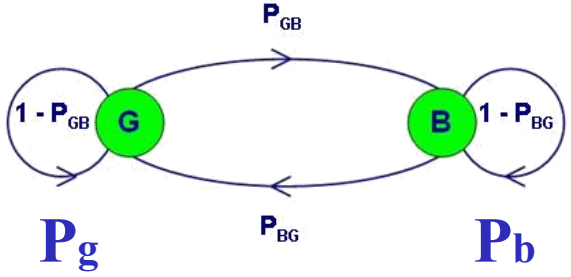
[Add:]

1. Realistic packet loss model
2. Different aggregation techniques
3. Opportunistic channel access

Packet Error Trace

100010101011010
110001010101010
101010101000101
010101011101010
…

2-state Markov Chain



Simulation. IEEE 802.11 system-level simulator

1. Event-driven C++code
   - High performance
   - Scalable

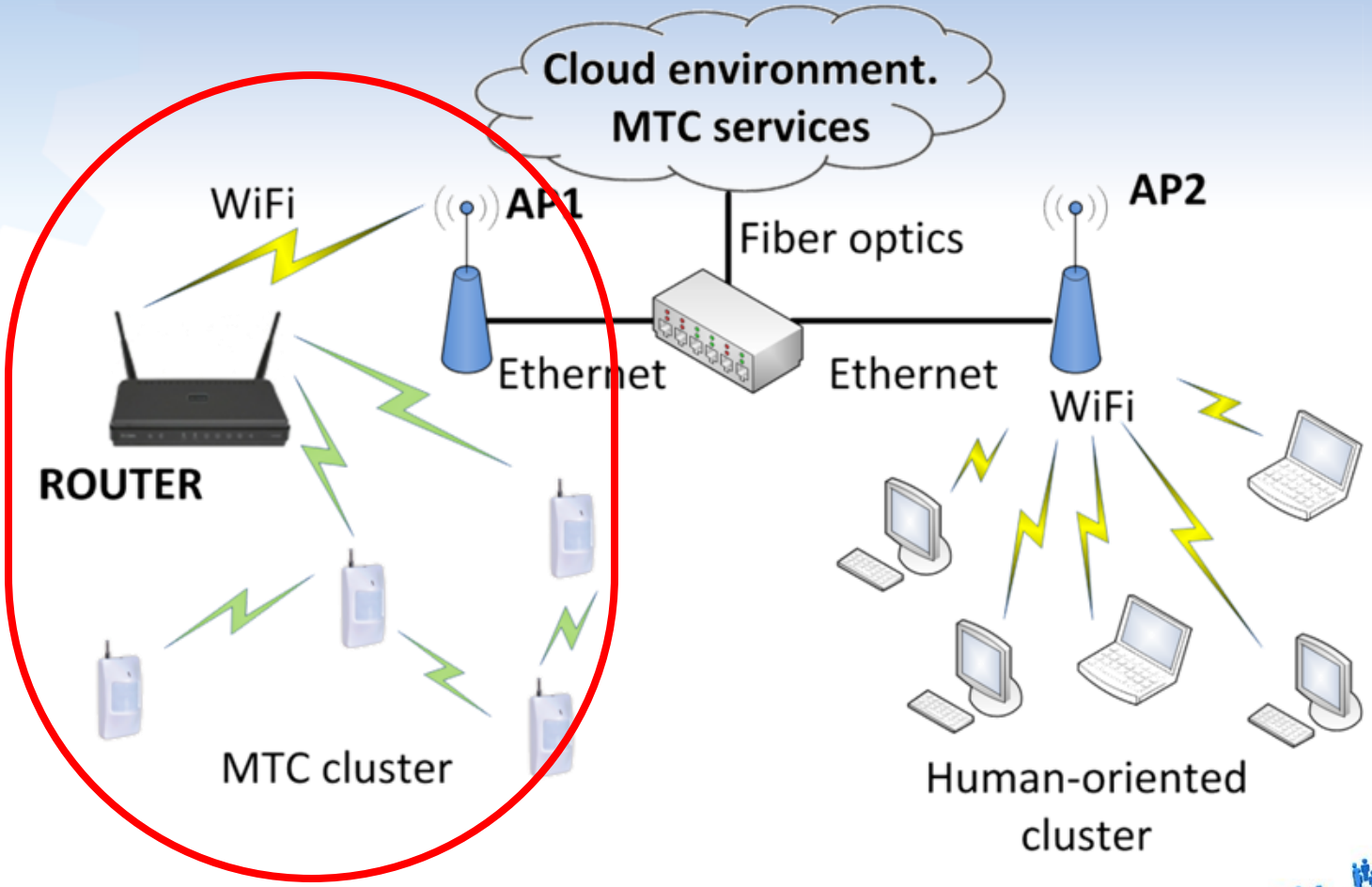
2. Different IEEE 802.11 releases
   - Conventional 802.11-2007
   - 802.11n-2009
   - 802.11-2012
   - 802.11ac
   - 802.11ah

3. Various traffic models
   - Uniform
   - Poisson/exponential
   - Beta
   - Full-buffer

4. Flexible statistics collection
   - Access latency/probability
   - Node state stats (Idle, Tx, Rx, etc.)

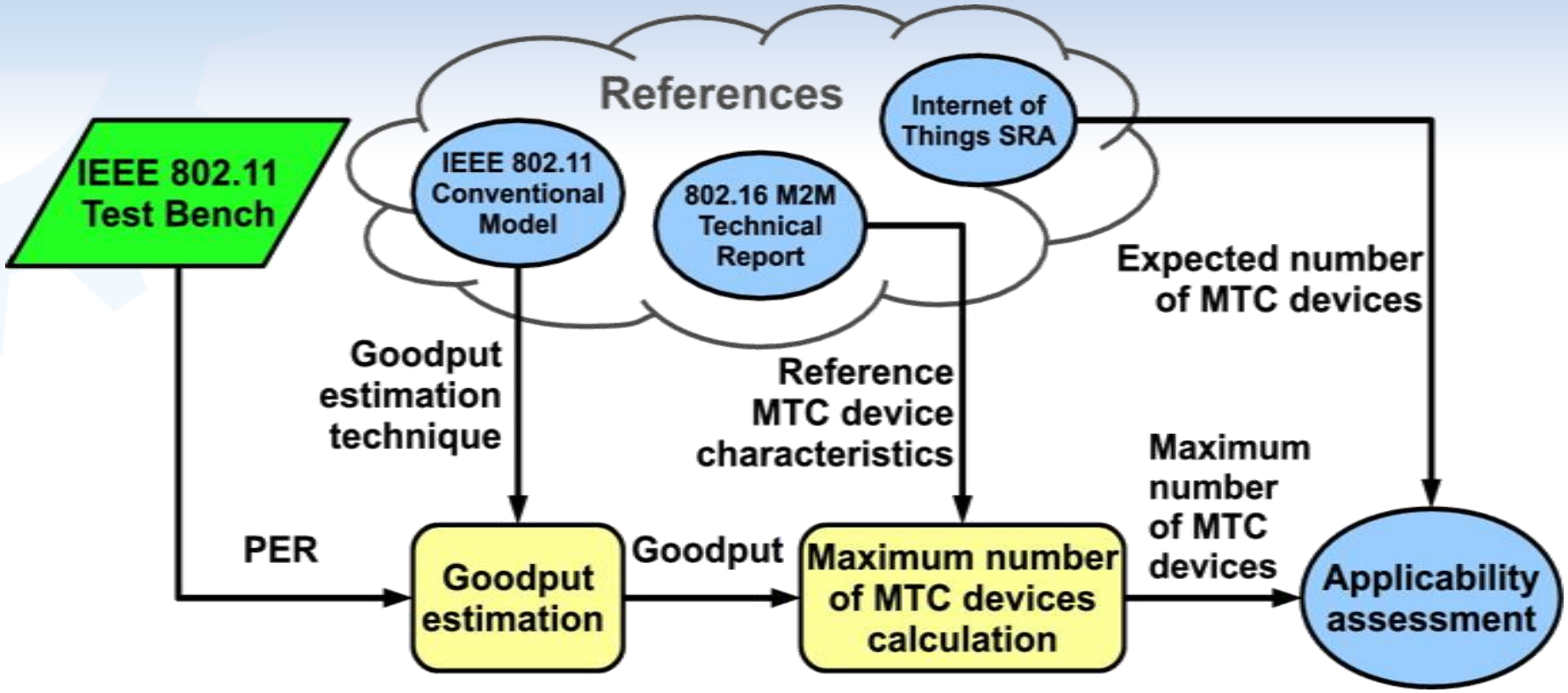
[Usage:] Applicable for emerging 802.11 releases (n, 2012, ac)
Supports variety of random multiple access technologies

IEEE 802.11 applicability for Machine-type Communications



* *G. Wu, S. Talwar, K. Johnsson, N. Himayat, N. D. Johnson, "M2M: From Mobile to Embedded Internet", IEEE Communications Magazine, 2011*

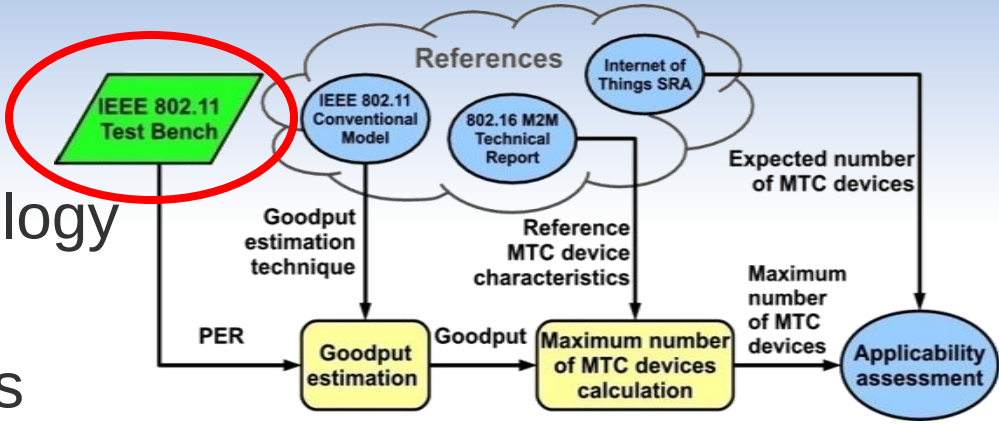
Assessment methodology



IEEE 802.11 test bench

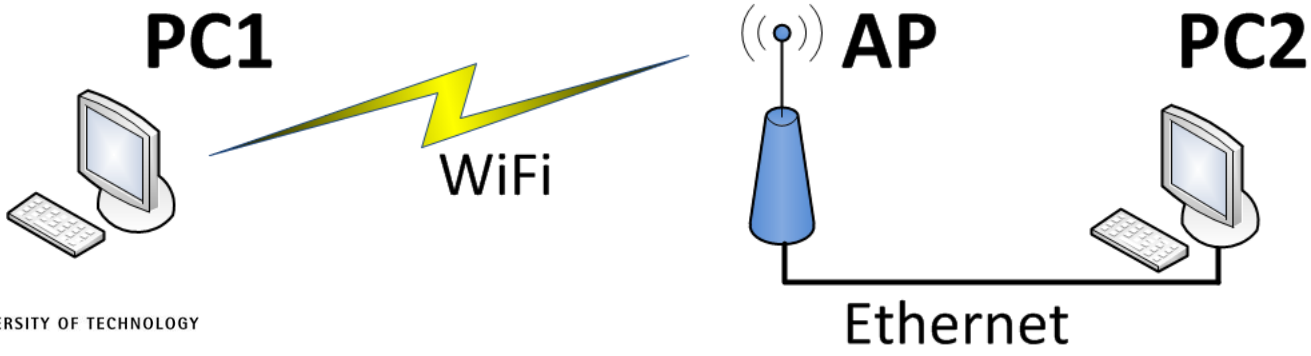
Measurement of PER

1. MTC aware use case
2. State-of-the-art technology
3. Saturated queues
4. Two signaling schemes



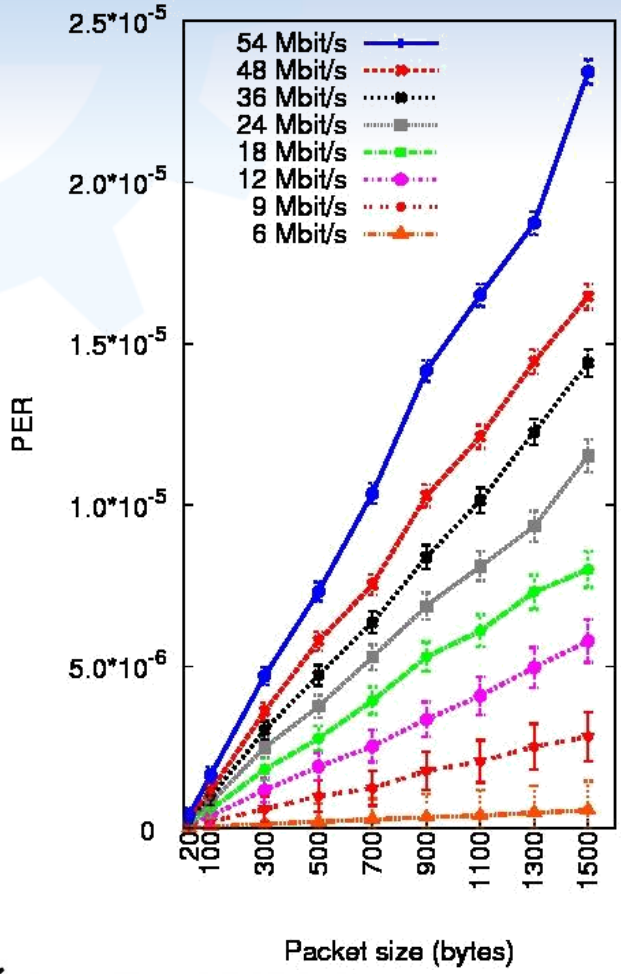
Open-source driver: *ath9k*

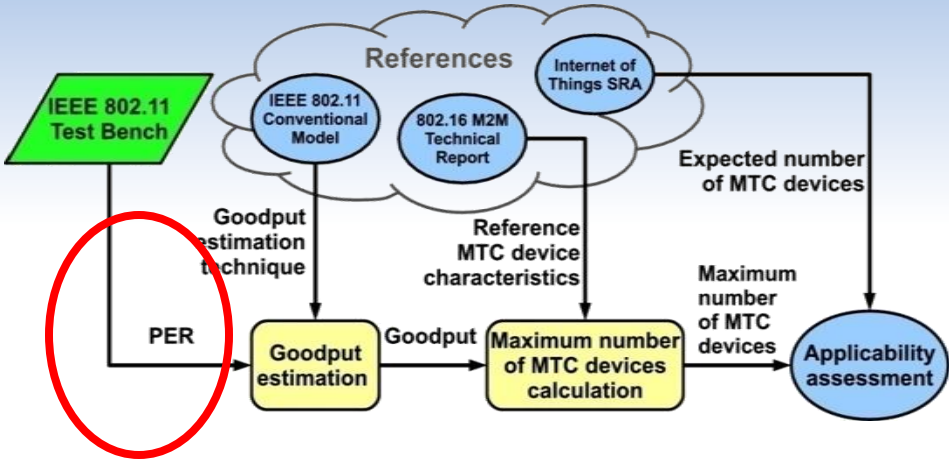
- Manual rate control
- No retries (genuine statistics)



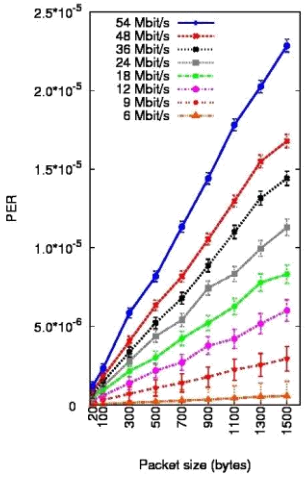
PER measurements

Basic scheme





RTS/CTS scheme

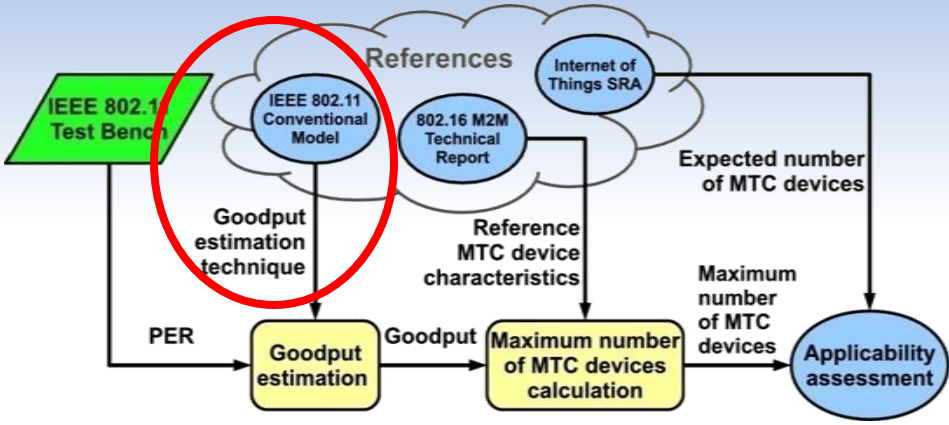


- Realistic levels of PER ***estimated***

Goodput prediction

Optimistic scenario:

- Full-buffer traffic
- Single link
- Fixed data rate
- Maximum power

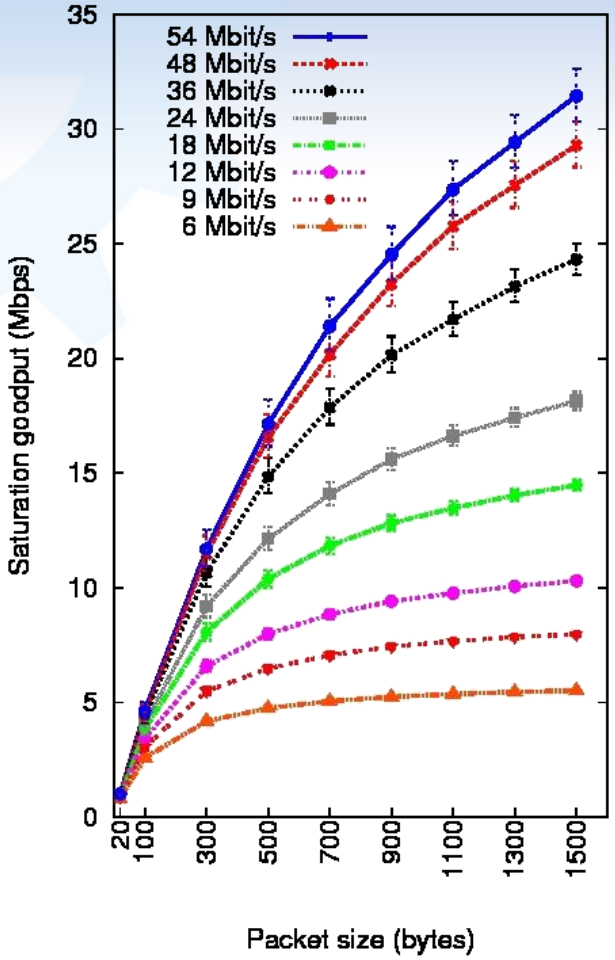


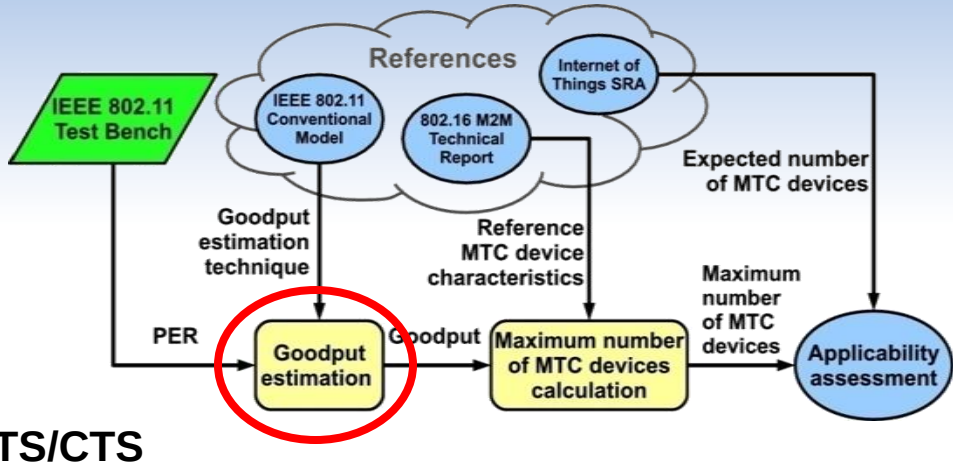
$$S = \frac{8 \cdot l_{data} \cdot (1 - p_e)}{(\frac{W_0}{2} \cdot t_{slot} + t_s) \cdot (1 - p_e) + t_e \cdot p_e \cdot \frac{p_e^N - 1}{p_e - 1} + W_0 \cdot t_{slot} \cdot p_e \cdot \frac{(2 \cdot p_e)^N - 1}{2 \cdot p_e - 1}}$$

$$S^* = \frac{8 \cdot l_{data} \cdot (1 - p_e)}{(\frac{W_0}{2} \cdot t_{slot} + t_s + t_h) \cdot (1 - p_e) + (t_e + t_h) \cdot p_e \cdot \frac{p_e^N - 1}{p_e - 1} + W_0 \cdot t_{slot} \cdot p_e \cdot \frac{(2 \cdot p_e)^N - 1}{2 \cdot p_e - 1}}$$

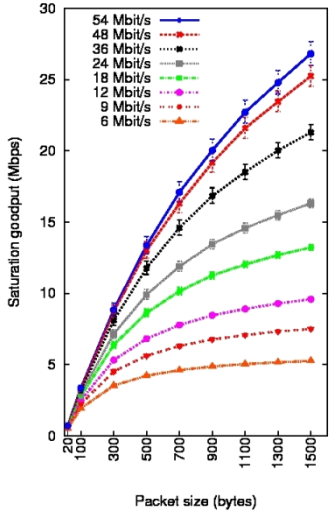
Goodput estimation

Basic scheme





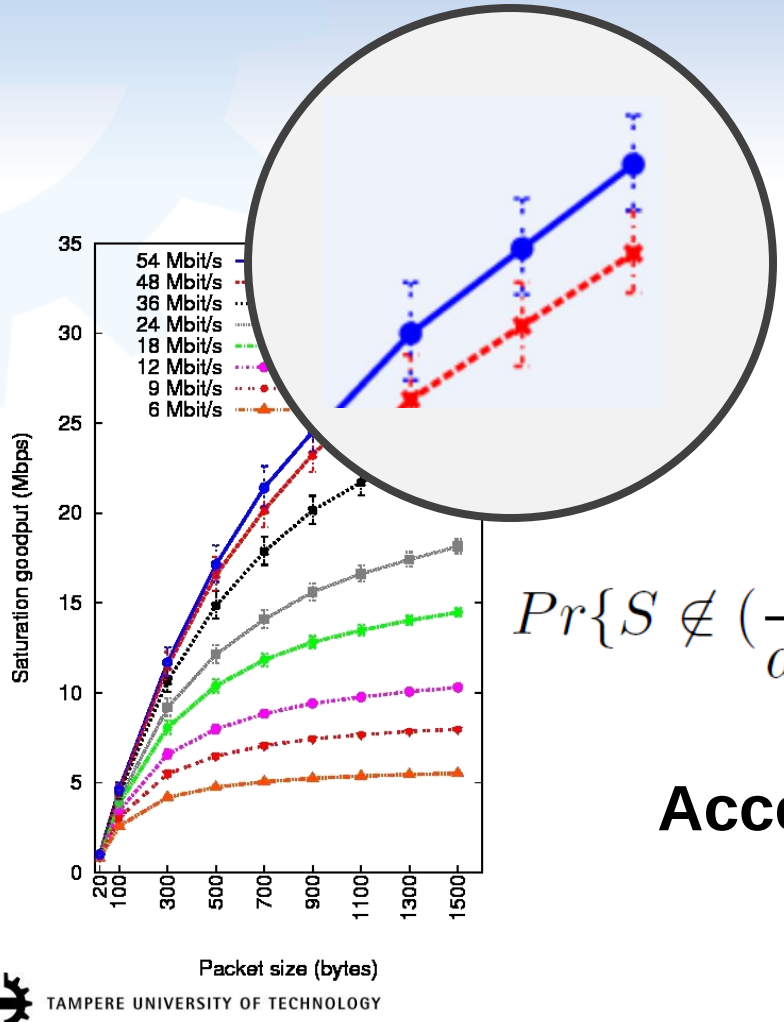
RTS/CTS scheme

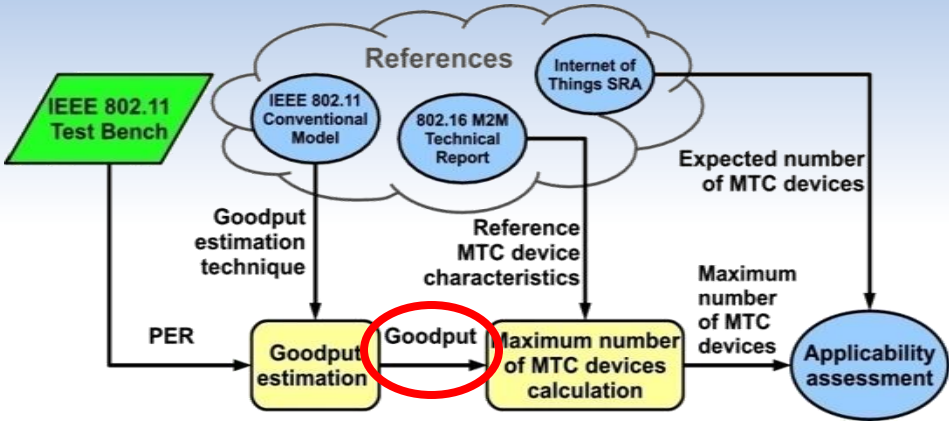


Semi-analytical model verified

G. Martorell, F. Riera-Palou, and G. Femenias, ”Closed-Loop Adaptive IEEE 802.11n with PHY/MAC Cross-Layer Constraints”, *MACOM 2011

Goodput accuracy

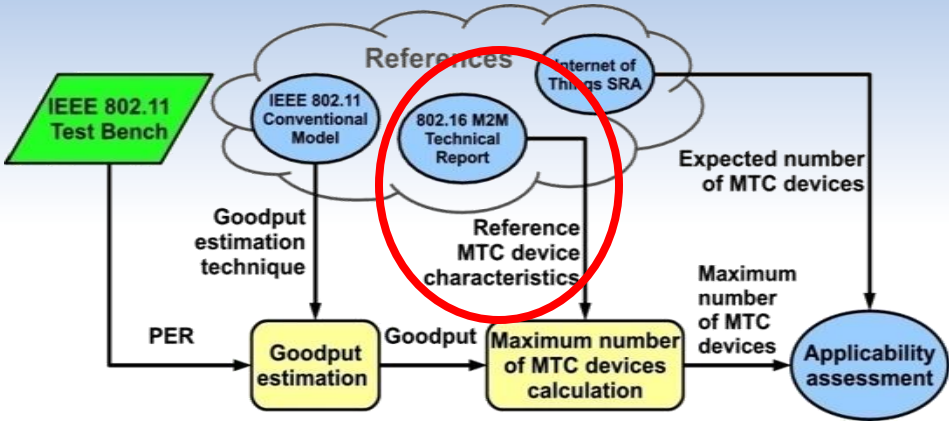




$$Pr\{S \notin (\frac{8 \cdot l_{data}}{d_b + \sigma_b/3}; \frac{8 \cdot l_{data}}{d_b - \sigma_b/3})\} \leq \frac{9}{M} \approx 10^{-8}$$

Acceptable accuracy level

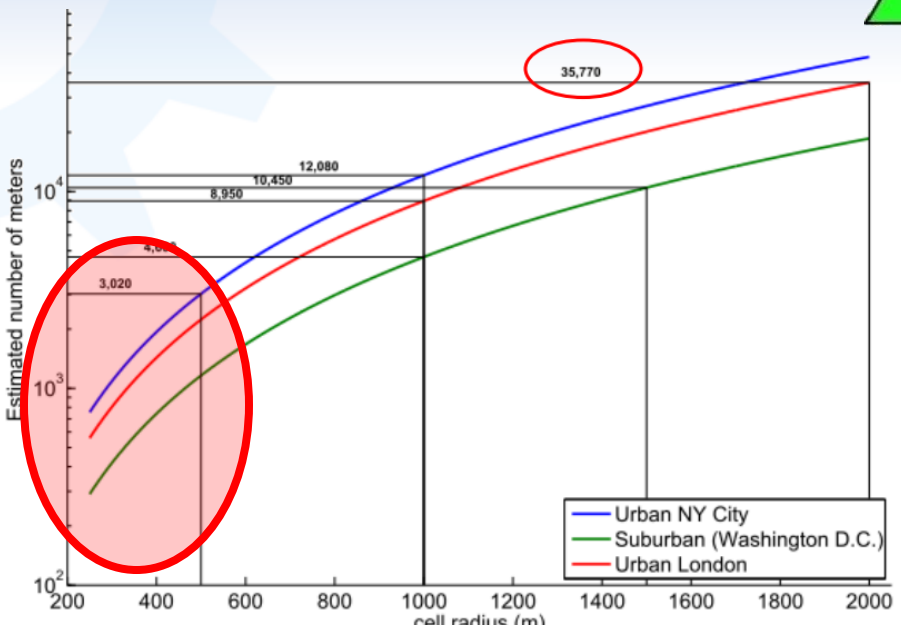
Reference MTC device

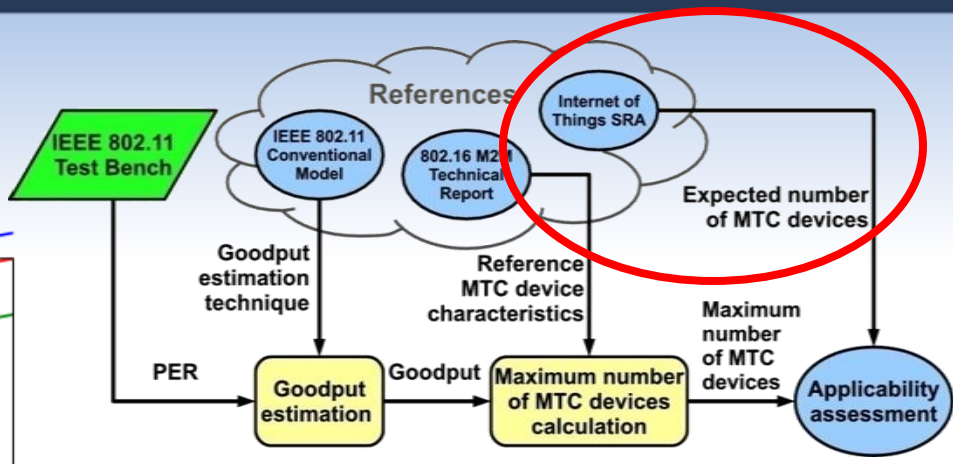


A typical MTC device	
Traffic rate	100 Kbps
Message size	~20 bytes

N. Himayat, S. Talwar, K. Johnsson, S. Andreev, O. Galinina, A. Turlikov, "Proposed IEEE 802.16p Performance Requirements for Network Entry by Large Number of Devices", IEEE 802.16 Broadband Wireless Access Working Group C80216p-10-0006, 2010.

Deployment requirements





A. Maeder, P. Rost, D. Staehle, "The Challenge of M2M Communications for the Cellular Radio Access Network", 11th Wurzburg Workshop on IP EuroView2011, 2011

- ❑ **Wi-Fi coverage area ~50 meters**
- ❑ **~200 MTC devices per cluster**

Numerical results (optimistic)

- ***Scalable*** MTC support is ***challenging***

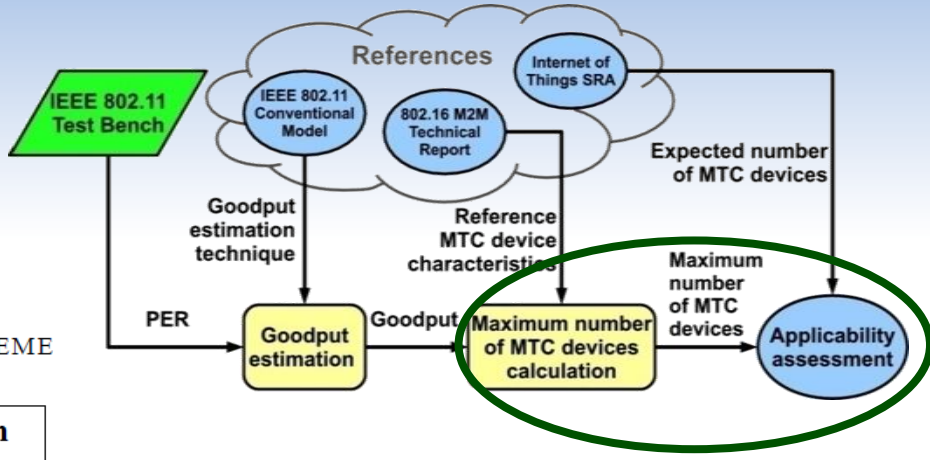


TABLE I
MAXIMUM SUPPORTED NUMBER OF MTC DEVICES. *Basic* SCHEME

Data rate (Mbps)	No aggregation	Aggregation at MAC layer	Aggregation at PHY layer
6	8	25	55
9	8	28	79
12	9	30	102
18	9	33	144
24	9	36	181
36	10	36	**243**
48	10	40	**293**
54	10	40	**314**

TABLE II
MAXIMUM SUPPORTED NUMBER OF MTC DEVICES. *RTS/CTS* SCHEME

Data rate (Mbps)	No aggregation	Aggregation at MAC layer	Aggregation at PHY layer
6	5	24	52
9	6	27	75
12	6	30	95
18	6	32	132
24	7	35	16[illegible]
36	7	35	**212**
48	7	39	**252**
54	7	39	**286**

V. Petrov, S. Andreev, Y. Koucheryavy, "Applicability Assessment of IEEE 802.11 Technology for Machine-Type Communications", in Proc. of 11th Annual Mediterranean Ad Hoc Networking Workshop, 2012

Challenges

- Application challenges
  - Small burst transmissions
  - Large number of devices
  - Tight battery budget
- Technology challenges
  - Contention-based access
  - High signaling overhead

Framework application for WWAN

- D2D Communications
  - * LTE + Wi-Fi (with Alexander)
  - — Coexistence of two radio technologies
  - — SLS analytical verification
- LTE RACH
  - * Overload control (with Mikhail)
  - — Energy and delay analysis of LTE-A

**M. Gerasimenko, V. Petrov, O. Galinina, S. Andreev, Y. Koucheryavy, "Energy and Delay Analysis of LTE-Advanced RACH Performance under MTC Overload", Globecom'12 - IWM2M, 2012*

Conclusions and current work

- Main results
  - Development of IEEE 802.11 test bench and SLS
  - Initial step toward flexible assessment methodology for random multiple access in existing wireless networks
    - Various usage models/scenarios
    - Diverse contention-based technologies
- Current work
  - Performance prediction for emerging IEEE 802.11 technologies ***(with TUT DCE)***
  - Different RAT comparison ***(with Ericsson and Aalto DCN)***
  - Study on security issues of beyond 4G networks ***(with Nokia Research)***

ERICSSON

Nokia Research Center

IEEE 802.11 test bench

Questions ?