Short-Range Communications within Emerging Wireless Networks and Architectures: A Survey

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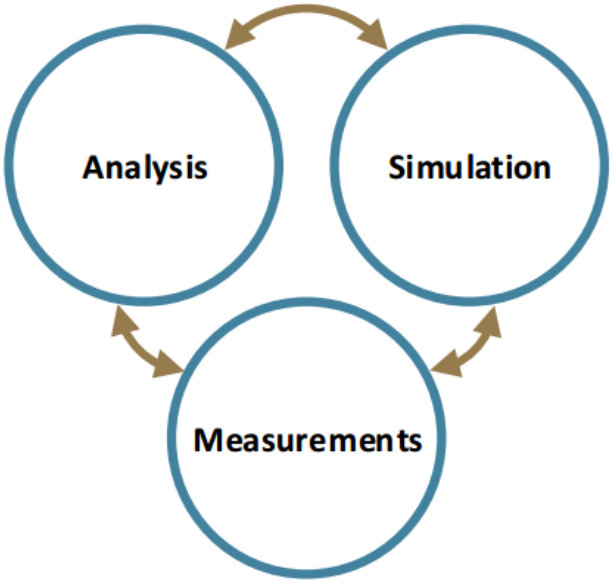
Outline

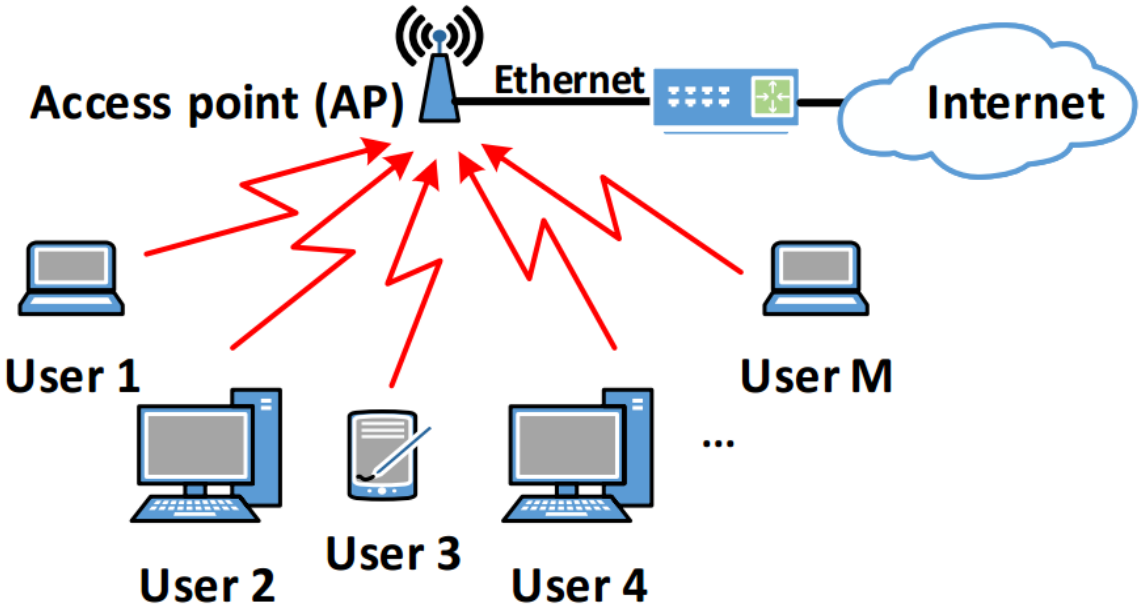
- Motivation in current WLANs
- Binary Exponential Backoff (BEB) protocol
- Regenerative analysis
- Validations
- Conclusions and future work

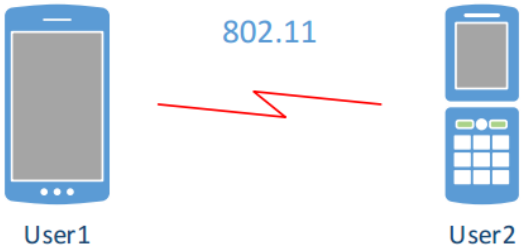
Goals

- Focus on the survey
- Identification model for modern network's evaluation
- Saturation throughput estimation
- IEEE 802.11-2012 calibrated simulator



Context

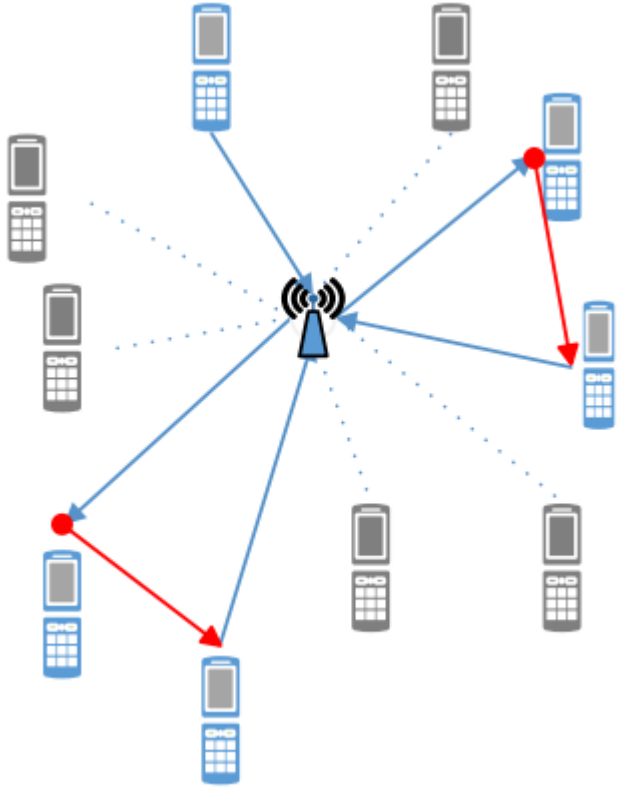




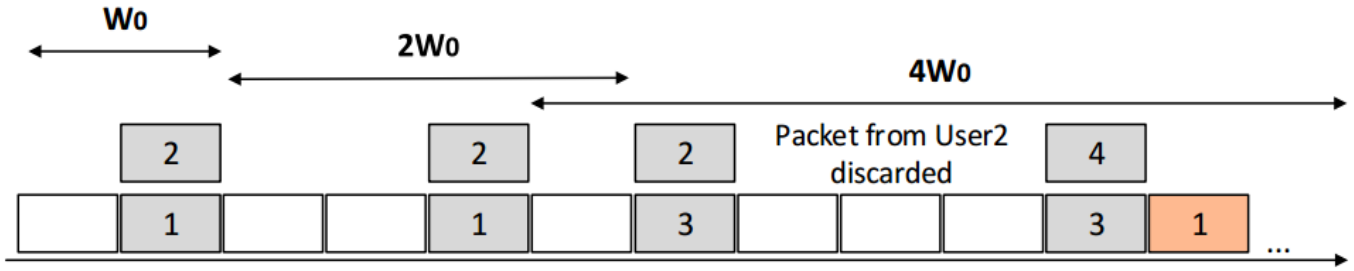
- IEEE 802.11-based network
- Uplink analysis
- M users
- Same data type
- **Saturated traffic**

Modeling Assumptions

- Communication system
  - Fixed topology
  - Synchronization
- Transmission Channel
  - IEEE 802.11-2012 timings
  - Saturated traffic
  - Noise-free environment
- Retransmissions
  - Lossless System (Conventional)
  - Lossy System (Limited number of retries)
- **Model** is similar to Bianchi's but **does not use Markov chain**
  - G. Bianchi, “Performance analysis of the IEEE 802.11 distributed coordination function”, *IEEE Journal on Selected Areas in Communications*, vol. 18, no. 3, pp. 535–547, 2000.



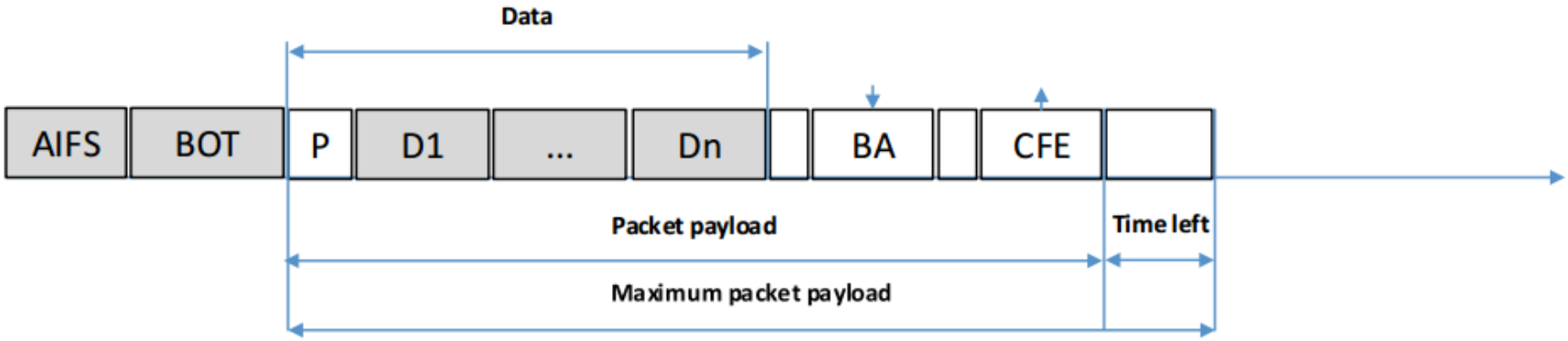
Binary Exponential Backoff (BEB)



- Bianchi's Lossless to **Lossy model** (Example for equally slotted system)
- **BEB stages** number *m*; *W0* **initial backoff window** size, **M** number of users
- Retransmission **attempts** number *K* (Infinite for Lossless, and finite for Lossy)
- **Conditional collision probability** for the system with **M** users:

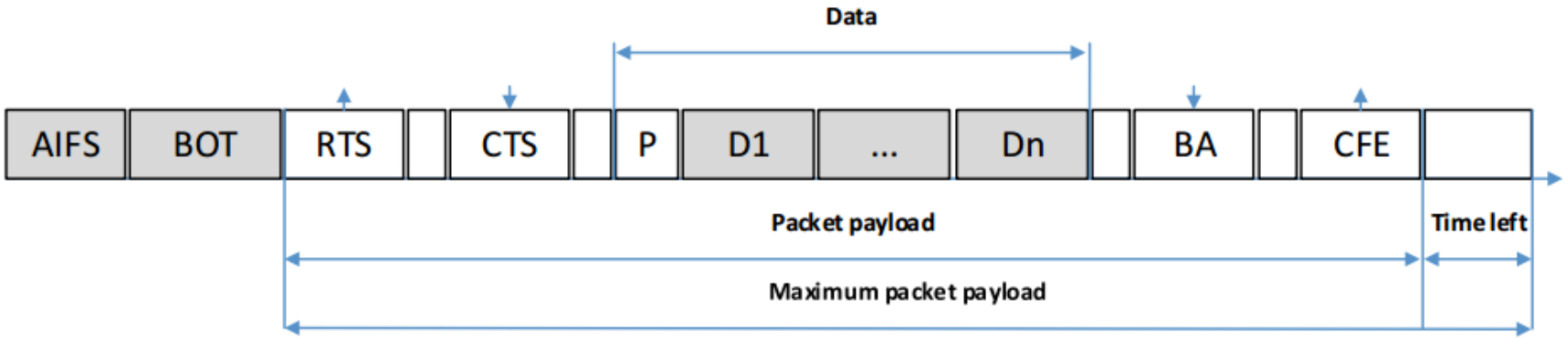
$$p_c = 1 - (1 - p_t)^{M-1}$$

Unequally-Slotted System



- Each slot is rescaled to the type of packet transmitted *(IEEE 802.11-2012)*
- Access mechanisms
  - Basic Access
    - AIFS – Arbitration Inter-Frame Spacing
    - BOT – random BackOff Time
    - BA – Block acknowledgment
    - CFE – Contention-Free End
  - RTS/CTS

Used RTS/CTS mechanism



- Noise-free channel
  - **Short Retry Limit** was used for Lossy system
- Protection against hidden terminal, reduce time waste due to collision
  - RTS – Ready-to-Send
  - CTS – Clear-to-Send

Main analysis

- Obtained with the use of regeneration cycle concept
  - Transmission probability:

$$p_t = \lim_{n\to\infty} \frac{\sum_{i=1}^{n} B^{(i)}}{\sum_{i=1}^{n} D^{(i)}} = \frac{E[B]}{E[D]}$$ where *E[B]* – average packet transmission attempts, *E[D]* – average cycle duration

$$E[B] = \sum_{i=1}^{K+1} i \Pr\{B = i\} = (1-p_c) \sum_{i=1}^{K+1} i p_c^{i-1} + (K+1) p_c^{K+1} = \frac{1-p_c^{K+1}}{1-p_c}$$

if *K+1 ≤ m*

$$E[D'] = (1-p_c)\left[\sum_{i=1}^{K+1}\left(2^{i-1}W_0 - \frac{W_0 - i}{2}\right)p_c^{i-1}\right] + p_c^{K+1}\left(2^K W_0 - \frac{W_0 - (K+1)}{2}\right)$$

K+1 > m

$$E[D''] = (1-p_c)\left[\sum_{i=1}^{m+1}\left(2^{i-1}W_0 - \frac{W_0 - i}{2}\right)p_c^{i-1} + \sum_{i=m+2}^{K+1}\left(2^{m-1}W_0(i-m+1) - \frac{W_0 - i}{2}\right)p_c^{i-1}\right] + p_c^{K+1}\left(2^{m-1}W_0(K-m+2) - \frac{W_0-(K+1)}{2}\right)$$

Final metrics

- Collision and Successful **slots duration:**

$$\begin{cases} T_s = RTS + SIFS + CTS + SIFS + H + E[P] + \\ \qquad\qquad + SIFS + BA + AIFS \\ T_c = RTS + AIFS. \end{cases}$$

- **Saturation throughput**:

$$S = \frac{P_t P_s E[P]}{(1-P_t)\sigma + P_t P_s T_s + P_t(1-P_s)T_c}$$

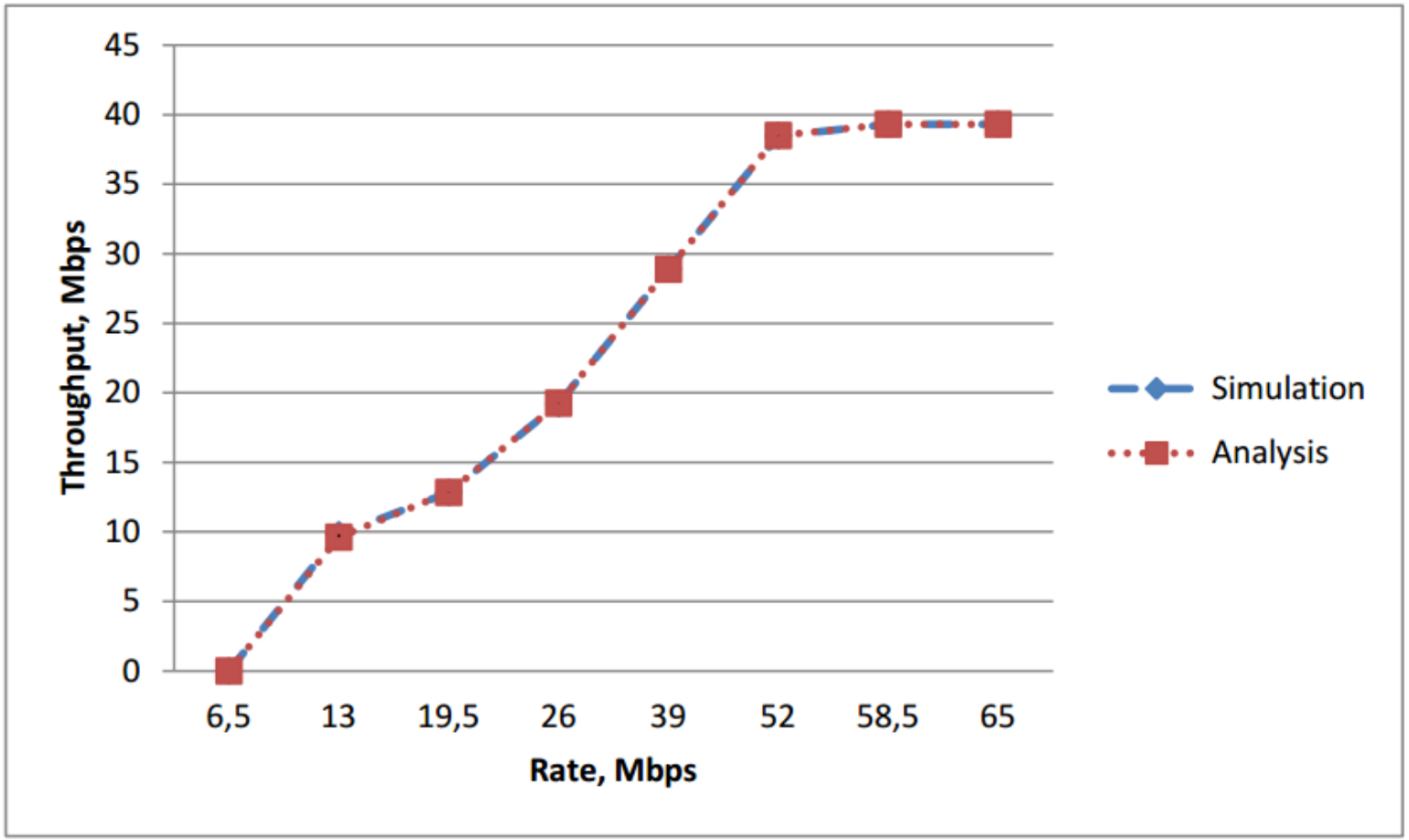
$$P_t = 1-(1-p_t)^M \quad P_s = M p_t (1-p_t)^{M-1}$$

- **Maximum D2D link throughput**:

$$C_{\mathrm{RTS/CTS}} \cong \frac{N_{pac} * Length_{pac}}{AIFS + M[BOT] + RTS + CTS + BA + CFE + 4*SIFS + \frac{N_{pac} * Length_{pac}}{R}}$$

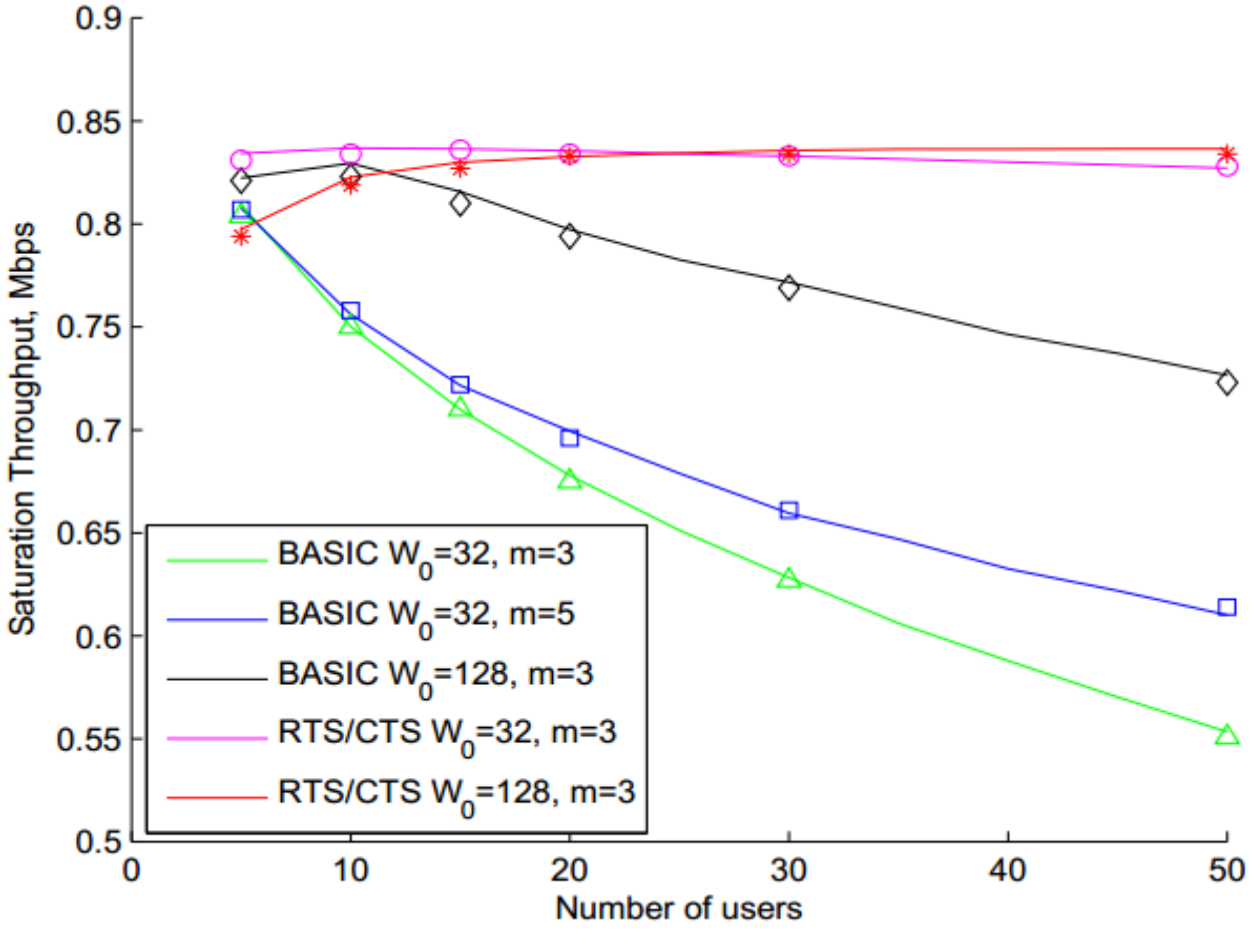
Throughput for Current Standard and

- *802.11-2012* Saturation throughput for *various* rates



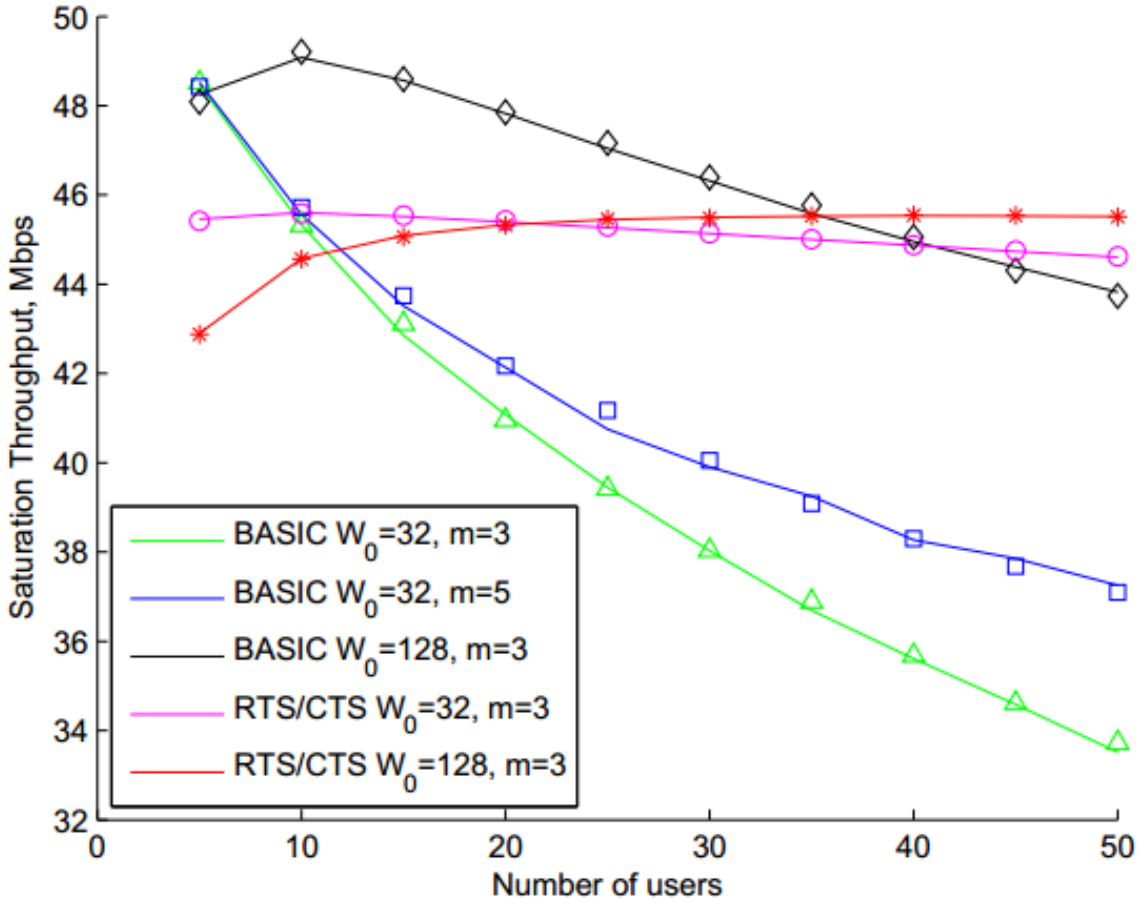
Model Calibration for Lossless system

- System calibration with Bianchi's data at *1 Mbps*



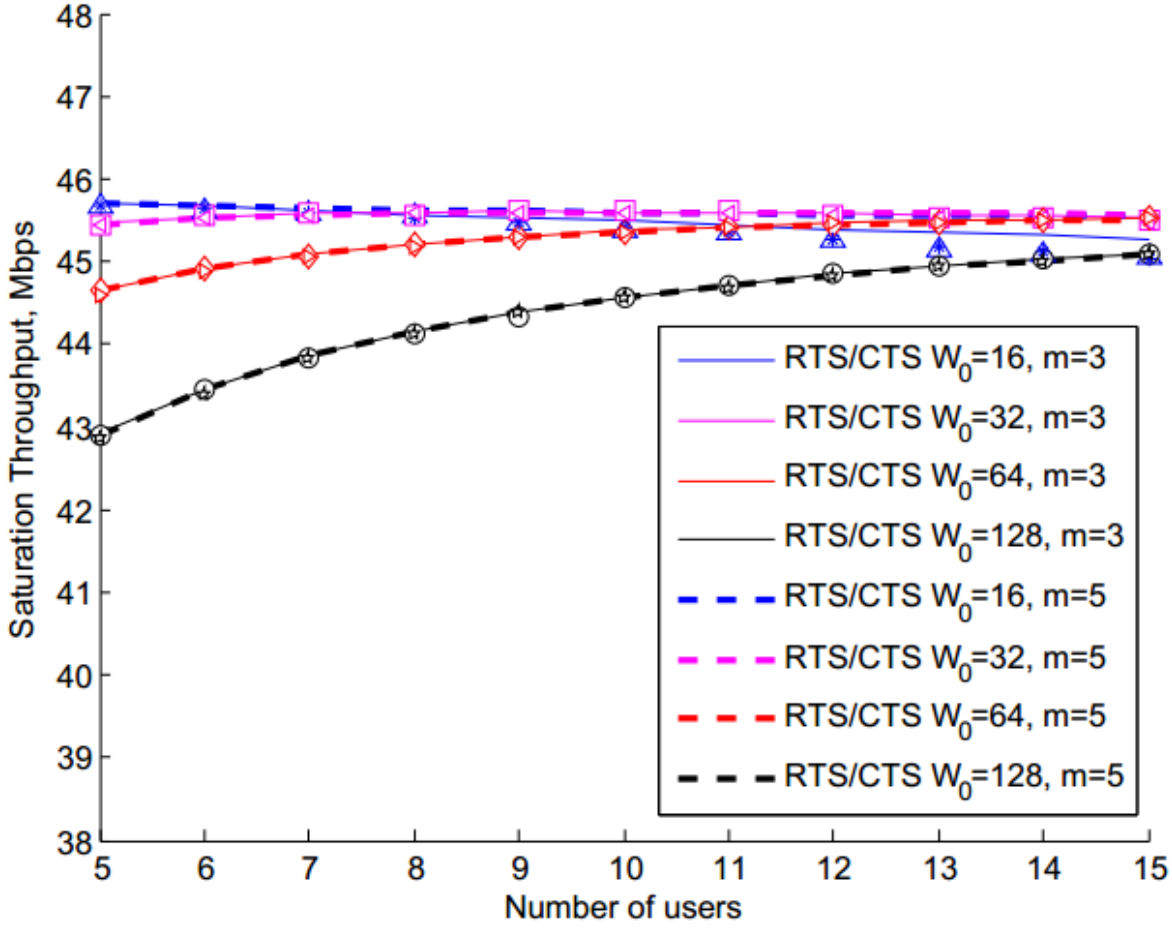
Timings for Current Standard

- *802.11-2012* Saturation throughput for *65 Mbps* rate



Results for Lossy system

- Maximum retransmission attempts number – *3*
- Rate - *65 Mbps*



Conclusions

- Simplified model that converges test bench, simulation, analytical approach
  - Proposed simple and flexible model, scales for many parameters
  - Enables saturation throughput estimation
- Future Work
  - Extending the model to metropolitan traffic conditions
  - Real channel effect

Thank you
for your attention

Questions?

Core system parameters

Parameter	Value
BitRate	$1.0, 53.0 MBps$
Number of users	$5 - 55$
Initial Back-off window	32
Back-off window power	3
Short Retry Limit	7
Modelling duration	$50\mu s$
Slot length	9μ
SIFS	16μ
Block Acknowledgement duration	48μ
Request-To-Send duration	48μ
Clear-To-Send duration	44μ
CF-End duration	44μ
Maximum Transmission Opportunity	1300μ
MAC Header	$244bits$