Research Directions in Low-Power Wireless Networks

Behnam Dezfouli

[dezfouli@ieee.org]

November 2014

Research Directions in Wireless Networks

❑ OBSERVING AND CHARACTERIZING THE EFFECT OF ENVIRONMENT ON WIRELESS COMMUNICATIONS

- For example, existing research confirms the higher variability of links in indoor environments due to a higher multipath effect, and wireless propagation around a transmitter is not isotropic.
- Investigating wireless communications for body networks is an important research area.
  - It is desirable to investigate how IEEE 802.15.6-compliant radios behave with respect to human tissues and mobility
  - The RF characteristics of the terahertz channel, which is used for nano-wireless sensor networks, is unknown

Papers:

- "Experimental study of concurrent transmission in wireless sensor networks", SenSys'06
- "An empirical study of low-power wireless", TOSN, 2010
- "An analysis of unreliability and asymmetry in low-power wireless links", TOSN, 2007
- "Calibrating RSSI Measurements for 802.15. 4 Radios", 2009
- "On accurate measurement of link quality in multi-hop wireless mesh networks", MOBICOM'06
- "Sniffing out the correct physical layer capture model in 802.11b", ICNP'04
- "On estimating joint interference for concurrent packet transmissions in low power wireless networks", WINTECH'08
- "How Environmental Factors Impact Outdoor Wireless Sensor Networks: A Case Study", 2013

Research Directions in Wireless Networks

❑ DEVELOPING NEW APPROACHES FOR MODELING WIRELESS COMMUNICATIONS

- Existing models should be improved, and new models are required to represent the characteristics of wireless communications
- Models of wireless communications can be used for:
  - Analytical analysis of network/protocols operation
  - Implementation in simulation tools

Papers:

- "What details are needed for wireless simulations? - A study of a site-specific indoor wireless model", INFOCOM'12
- "A Channel Model for the Bit Error Rate Process in 802.15.4 LR-WPAN Wireless Channels", ICC'08
- "Investigating a physically-based signal power model for robust low power wireless link simulation", MSWIM'08
- "Models and solutions for radio irregularity in wireless sensor networks", TOSN, 2006

Research Directions in Wireless Networks

❑ IMPROVING THE ACCURACY OF SIMULATION TOOLS

- This allows performance evaluation with higher accuracy
- Enables the researchers to highlight the drawbacks of existing protocols in realistic conditions, and design protocols that perform desirably in real-world conditions

Papers:

- "What details are needed for wireless simulations? - A study of a site-specific indoor wireless model", INFOCOM'12
- "On the impact of far-away interference on evaluations of wireless multihop networks", MSWIM'09
- "Overhaul of IEEE 802.11 modeling and simulation in ns-2", MSWIM'07
- "CAMA: Efficient modeling of the capture effect for low-power wireless networks", TOSN,2014
- "Improving wireless simulation through noise modeling", IPSN'07
- "Improved modeling of IEEE 802.11a PHY through fine-grained measurements", Computer Networks, 2010
- "Modeling low-power wireless communications", JNCA, 2014

❑ TO DEVELOP NEW APPROACHES FOR EFFICIENT IMPLEMENTATION OF WIRELESS COMMUNICATION MODELS

- A model must be implemented in an efficient way in order to provide fast performance evaluation
- Algorithm design and software development

Papers:

- "CAMA: Efficient modeling of the capture effect for low-power wireless networks", TOSN,2014
- "Modeling low-power wireless communications", JNCA, 2014

Research Directions in Wireless Networks

- **EVALUATING THE EFFECT OF EXTERNAL INTERFERENCE ON NETWORK PERFORMANCE**
  - Many types of wireless networks, and in particular, wireless body area networks, are used in interference prone environment
  - It is desirable to investigate how external interference affects these networks. This issue is also referred to as coexistence
  - For example, wireless body networks using IEEE 802.15.4 can be highly affected by IEEE 802.11
  - Challenges of coexistence should especially be considered at the physical and MAC layer (channel switching, power control, etc.)

Papers:

- "Improving wireless simulation through noise modeling", IPSN'07
- "Packet Error Rate Analysis of IEEE 802.15.4 Under IEEE 802.11b Interference", 2005
- "A Coexistence Model of IEEE 802.15.4 and IEEE 802.11b/g", 2007
- "Experimental Study of the Impact of WLAN Interference on IEEE 802.15.4 Body Area Networks", EWSN'09

Research Directions in Wireless Networks

❑ DESIGNING MEDIUM ACCESS CONTROL PROTOCOLS

- As the wireless channel is a broadcast medium, it is the responsibility of MAC to control access to the channel and try to avoid packet collision
- As MAC protocol controls radio operation (transmit, receive, sleep), it highly affects energy efficiency
- CSMA-based MACs have low complexity and can handle low traffic rates; TDMA-based MACs have high complexity and can handle high traffic rate
- Combination of CSMA and TDMA is referred as hybrid MAC, and has attracted attention
- Designing scheduling algorithms and power control mechanisms are highly related to the development of MAC protocols

Papers:

- "DICSA: Distributed and concurrent link scheduling algorithm for data gathering in wireless sensor networks," Ad Hoc Networks, vol. 25, pp. 54–71, Feb. 2015.
- "MAC Essentials for Wireless Sensor Networks", IEEE, 2010
- "DRAND: Distributed Randomized TDMA Scheduling For Wireless Ad-hoc Networks", MOBICOM'06
- "Ultra-low duty cycle MAC with scheduled channel polling", Sensys'06
- "Z-MAC: A Hybrid MAC for Wireless Sensor Networks", IEEE, 2008
- "Funneling-MAC: a localized, sink-oriented MAC for boosting fidelity in sensor networks", SenSys,'06
- "Improving Broadcast Reliability for Neighbor Discovery, Link Estimation and Collection Tree Construction in Wireless Sensor Networks", Computer Networks, 2014

Research Directions in Wireless Networks

❑ MODELING CHANNEL ACCESS PROTOCOLS

- Developing a mathematical model that can represent the operation of a MAC protocol and its achieved network throughput is highly desirable
- Such a model enables fast adjustment and evaluation of channel access mechanisms

Papers:

- "DICSA: Distributed and concurrent link scheduling algorithm for data gathering in wireless sensor networks," Ad Hoc Networks, vol. 25, pp. 54–71, Feb. 2015.
- "CSMA/CA performance under high traffic conditions: throughput and delay analysis", ComCom'02
- "Modeling Per-Flow Throughput and Capturing Starvation in CSMA Multi-Hop Wireless Networks", INFOCOM'06
- "Performance Analysis of Contention Based Medium Access Control Protocols", IEEE, 2009
- "Throughput Model of IEEE 802.11 Networks with Capture Effect", 2006
- "Modeling Per-Flow Throughput and Capturing Starvation in CSMA Multi-Hop Wireless Networks", 2006
- "Modeling the S-MAC protocol in single-hop wireless sensor networks", 2008

Research Directions in Wireless Networks

❑ DESGINGING ROUTING PROTOCOLS

- Packets should be routed through paths that result in lower energy consumption, lower packet loss, and higher delivery rate
- Many routing protocols have been proposed for various types of wireless networks
- However, routing in body area networks is a challenging area
- These routings should avoid data forwarding thorough congested and hot nodes.

Papers:

- "Multipath routing in wireless sensor networks: survey and research challenges.", Sensors, 2012
- "LIEMRO: A low-interference energy-efficient multipath routing protocol for improving QoS in event-based wireless sensor networks", SENSORCOMM, 2010
- "Enhanced tree routing for wireless sensor networks", Ad Hoc Networks, 2009
- "ExOR: opportunistic multi-hop routing for wireless networks", 2005
- "Routing Metrics of Cognitive Radio Networks: A Survey", IEEE, 2014

❑ LINK ESTIMATION

- Protocols such as routing and link scheduling require link quality information

Papers:

- "Integration and Analysis of Neighbor Discovery and Link Quality Estimation in Wireless Sensor Networks", 2014
- "Coping with unreliable channels: Efficient link estimation for low-power wireless sensor networks", 2008
- "Radio link quality estimation in wireless sensor networks: A survey", TOSN, 2012

Research Directions in Wireless Networks

- **CROSS-LAYER DESIGN**
  - In contrast to wired networks, protocol design cannot be merely considered at a single layer
  - Especially, each layer requires information and interaction with other layers to achieve desirable performance
  - For example, MAC protocols can benefit from power control

Papers:

- "Integration and Analysis of Neighbor Discovery and Link Quality Estimation in Wireless Sensor Networks," Sci. World Journal, Hindawi, vol. 2014, pp. 1–23, 2014.
- "Optimal routing, link scheduling and power control in multihop wireless networks", 2003
- "Cross-layer design for lifetime maximization in interference-limited wireless sensor networks", 2006
- "Cross-Layer Analysis of the End-to-End Delay Distribution in Wireless Sensor Networks", 2012
- "A cross-layer approach for minimizing interference and latency of medium access in wireless sensor networks", 2010

Other research topics:

- **COGNITIVE RADIO AND COGNITIVE MAC**
  - Wireless spectrum is a scarce resource and should be used wisely
- **SECURITY OF WIRELESS BODY AREA NETWORK, AND SECURE TRANSMISSION TO THE CLOUD**
  - The privacy of medical and health related data is of high importance

Journals and Conferences

Journals:

- Computer Networks, Elsevier
- Ad Hoc Networks, Elsevier
- Communications, Elsevier
- Transactions on Sensor Networks, ACM
- Transactions on Wireless Networks, IEEE
- Wireless Networks, Springer
- …

Conferences:

- INFOCOM
- SENSYS
- MOBICOM
- IPSN
- MOBISYS
- GLOBECOM
- …

Thank You…

Behnam Dezfouli

[dezfouli @ ieee.org]