Medium Access Control Protocols for Broadband Wireless Networks: Overview of Ongoing Research and Open Problems

Dr. Alexey V. Vinel

Institute for Information Transmission Problems Russian Academy of Sciences

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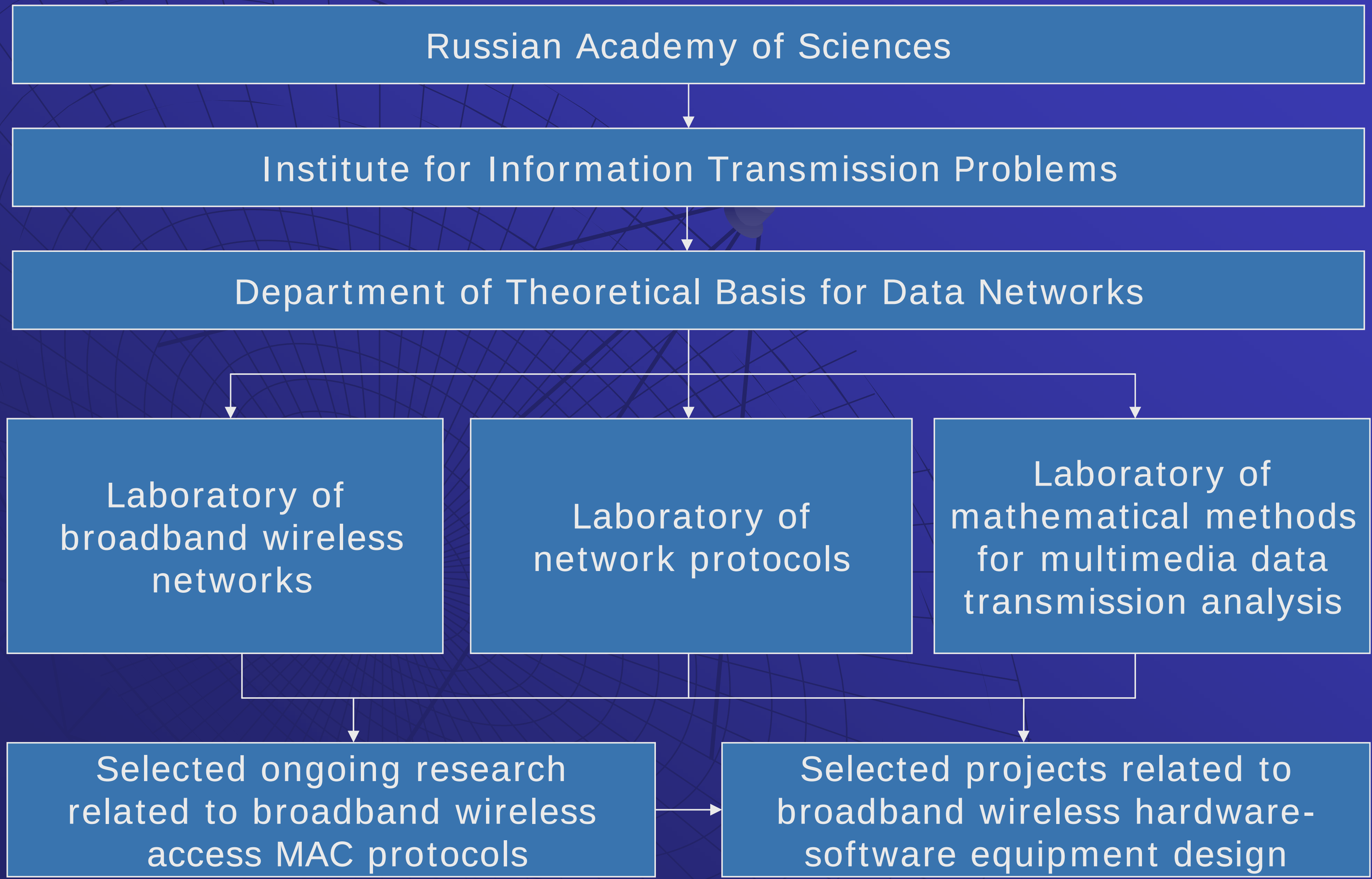
Organizational framework



Selected ongoing research topics

IEEE 802.11 MAC:

- ✓ Analysis of Direct Transmissions
- ✓ Reliable Multicast Transmissions
- ✓ Achieving High MAC Throughput in IEEE 802.11n
- ✓ Analysis of RA-OLSR in IEEE 802.11s Mesh

IEEE 802.16 MAC:

- ✓ Analysis of Random Access Efficiency
- ✓ Analysis of Multicast Polling
- ✓ Frame Structure Optimization
- ✓ Power-saving Schemes for IEEE 802.16e

Adaptive polling methods for IEEE 802.11 PCF mode and IEEE 802.16 PMP

Achieving High MAC Throughput in IEEE 802.11n

For high-speed CSMA/CA system ratio

$$\frac{\text{[Collision detection time]}}{\text{[Packet transmission time]}}$$

[Collision detection time] = const (Slot Time, PHY dependent)

[Packet transmission time] decreases as PHY-rate increases

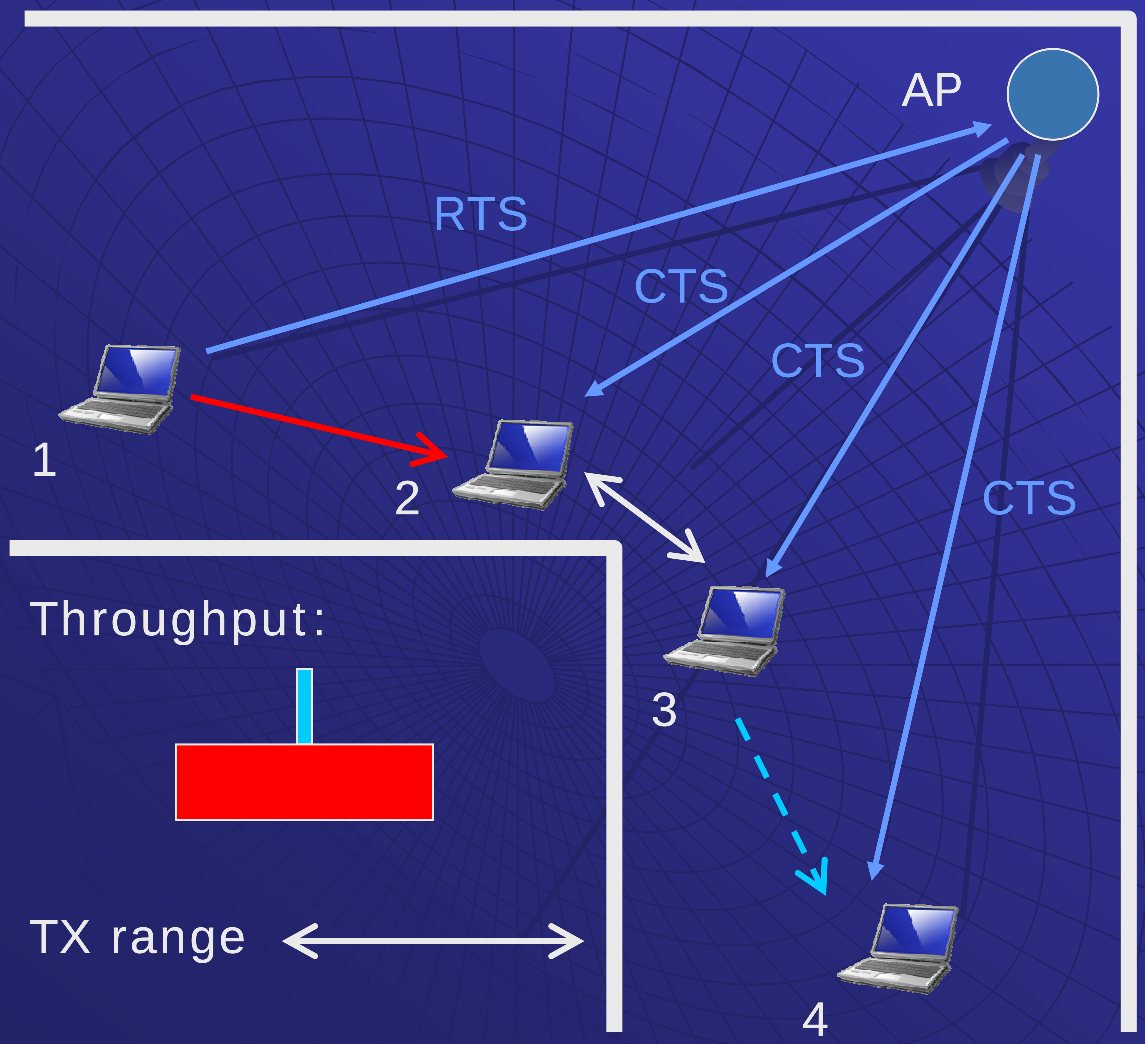
decreases

Importance of collision resolution algorithm increases

Concatenation and packing mechanisms

Enhancement of binary exponential backoff or alternative algorithms

Analysis of Direct Transmissions in IEEE 802.11(e)



Current proposal:

- ✓ Always use RTS/CTS
- ✓ Always use BAR/Block ACK
- ✓ Protect direct transmission:
  - QSTA -> RTS -> AP
  - AP -> CTS -> QSTA
  - direct transmission

Open problems:

- ✓ Unfairness between direct and indirect links
- ✓ Benefits of spatial reuse are wasted

Activities are performed within the IEEE 802.11 DLS Study Group

Reliable Multicast Transmissions in IEEE 802.11

Low reliability

Leader-Based Protocol (LBP) :
(Leader: CTS, ACK, NCTS, NAK; others : NCTS, NAK) (Kuri, Kasera, 2001)

Limitations of LBP: Security, NCTS-NAK
Propose: "worst condition leader"
(INRIA, LG Electronics, 2007)

Random Leader Technique
(Chao, Chang, Chen, 2001)

Large overhead

Broadcast Medium Window (BMW):
(Each broadcast transmission = multiple unicast transmission, only RTS-CTS-DATA-ACK are used)
(Tang, Gerla, 2001)

Batch Mode Multicast MAC (BMMM):
(RTS-CTS for all recipients, then DATA, then RAK-ACK for all)
(Sun, Huang 2002)

Enhanced LBP:
RTC-CTS-DATA batch-BAR_1-BACK_1-...-BAR_J-BACK_J
J ACK-leaders (based on PER) <= N multicast recipients

Analysis of Random Access Efficiency in IEEE 802.16

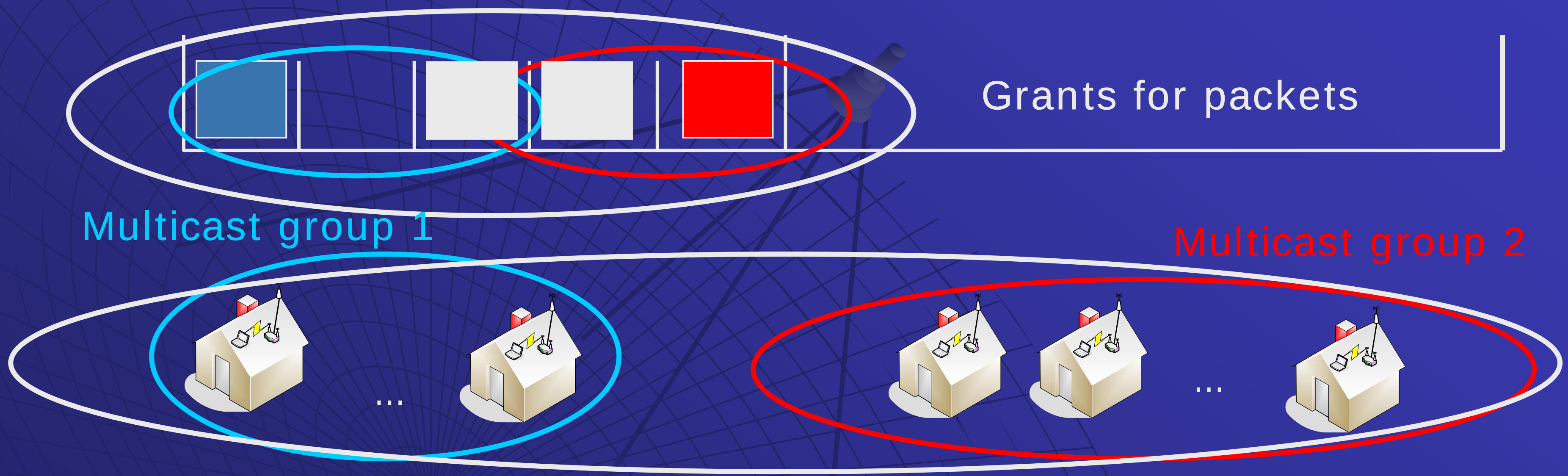
- ✓ Optimize the performance of the binary exponential backoff (BEB) in the framework of IEEE 802.16
- ✓ Compare the performance of unicast and broadcast polling BW-REQ delivery methods
- ✓ Introduce enhancements for the BEB such as Multi-FS-ALOHA

Ni Q., Vinel A., Xiao Y., et. al.
Investigation of Bandwidth Request Mechanisms under Point-to-Multipoint Mode of WiMAX Networks // IEEE Communications Magazine, Vol. 45, № 5, 2007.
Rated as one of the ten most popular articles published in ComSoc, as a 47th of the IEEE Top-100 in June 2007 and as a 82nd in August 2007.

Vinel A., Zhang Y., Ni Q., Lyakhov A. Efficient Request Mechanisms Usage in IEEE 802.16 // Proc. of 49th IEEE Global Telecommunications Conference – GLOBECOM'06, San Francisco, California, USA, 2006.

Analysis of Multicast Polling in IEEE 802.16

Uplink sub-frame: K transmission opportunities for random access



- ✓ We have proven, that introducing multicast polling if QoS requirements are not taken into account it is principally impossible to increase the throughput!
- ✓ Open problem: if different connections have different QoS requirements, how can we get benefits of multicast polling?

Frame Structure Optimization for IEEE 802.16

Transmission opportunities for BW-REQs ⟷ Grants for MAC PDU

Fixed uplink sub-frame duration

2 opposite requirements:

Large number of transmission opportunities for reservation;	Large amount of bandwidth for MAC PDU;

- ✓ We have shown which frame structure should be used to maximize the throughput!
- ✓ Open problem: which frame structure should be used to minimize the delay?

Power-saving Schemes for IEEE 802.16e

Power consumption ratio ⟷ Mean delay for the downlink packets transmission

Power Saving Class Type 1

MS want to save more energy increasing the initial sleeping window	BS has to wait for the nearest listening window if it has new MAC PDUs to transmit

- ✓ We have developed the analytical model for the power saving class type 1 operation
- ✓ Open problem: simple solution (existing ones use Laplace-Stieltjes transforms apparatus)

Adaptive Polling Methods for Broadband Wireless Networks

Detailed mathematical models of adaptive polling for IEEE 802.11 PCF for two scenarios:
- "collecting the information";
- "downloading from the access point".

The algorithms integrate different criterions to skip the queues (length of the queue in current moment of time, length of the queue in previous moments of time, the importance of this queue).

Open problem:

Apply the developed adaptive polling algorithms in the framework of WiMAX and compare the two technologies for metropolitan scenarios

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New book of Institute for Information Transmission Problems to be published by the beginning of 2008 "Polling systems in broadband wireless networks"

Practical Implementation Example: Wireless Router "RAPIRA"

- ✓ PMP with support of dynamic polling
- ✓ 2.3–2.5, 4.9–6.1 GHz and 6.0-6.4 GHz
- ✓ IEEE 802.11a compatible
- ✓ Up to 40 Mbs throughput
- ✓ Own software, which can be modified

Some Current R&D Collaborations in MAC protocols

- Saint-Petersburg State University of Aerospace Instrumentation, Russia

- Bulgarian Academy of Sciences

- University of Wuerzburg, Germany

- Brunel University, London, UK

- Korea University, Seoul, Korea

Contact Information

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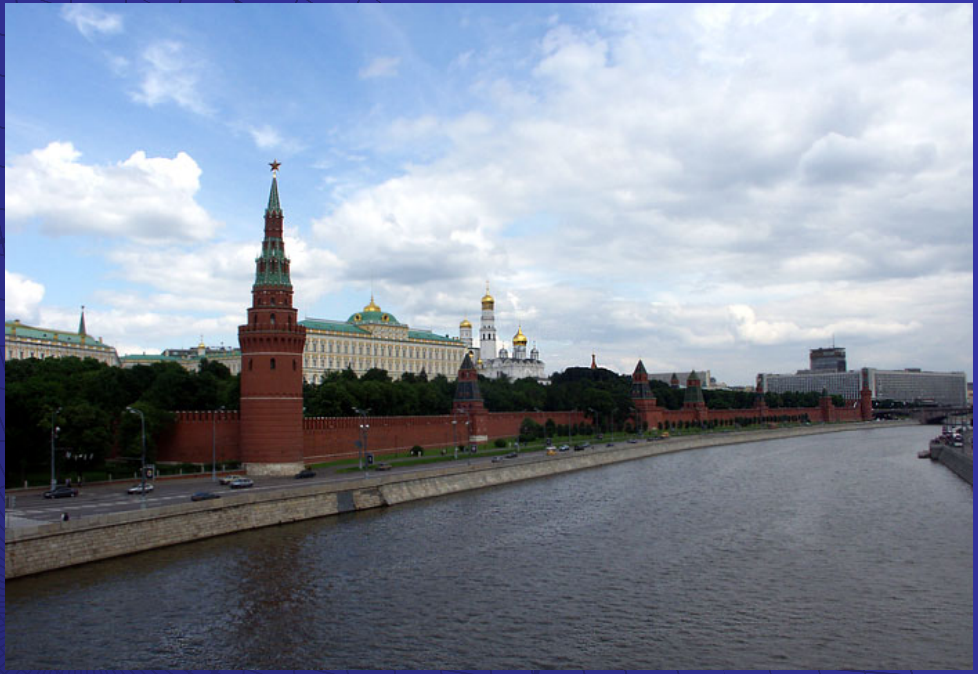

Please direct all enquiries to:

Alexey Vinel
vinel@ieee.org