

NiuLab

(Network integration for ubiquitous Linkage and broadband)

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2009-07-20 **TNList**

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Contents

- ❖ Introduction to THU, SIST, and TNList
- ❖ **Vision and Mission of NiuLab**
- ❖ **Major Research Topics**
 - MANET and WSN for *always-be-connected*
 - MRMC Networks for *always-best-connected*
 - Triple-play Network Integration for *always-best-connected*
 - *Multi-Dimensional* Radio Resource Management
 - *Power-efficient* New Generation Networks
- ❖ **Summary**

Wireless Communication Researches in THU

❖ Major Research Subjects

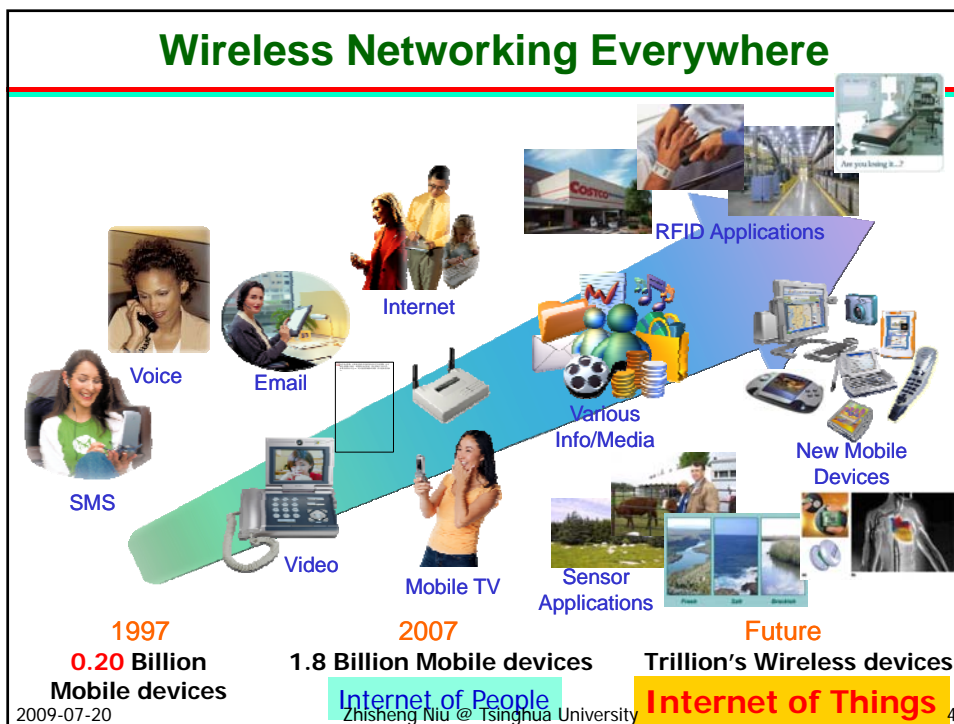
- Microwave, antenna, and spatial signal processing
(*Propagation, RF,*)
- Electromagnetic Interference and Electromagnetic Compatibility (*EMC,*)
- Source coding and system-on-chip technology (*AVS, mobile multimedia,*)
- Channel coding and wireless transmission systems (*3G/4G, DTV, Satellite,*)
- **Multiple access technologies and wireless networking**
(***WLAN, MANET, WSN, WMN, Cellular,***)

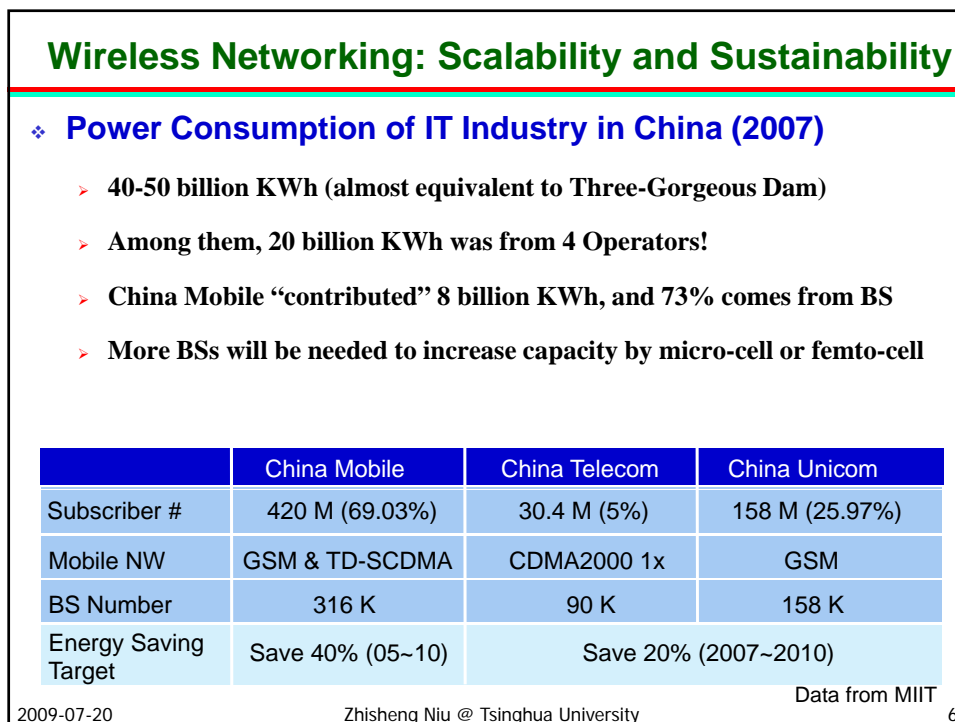
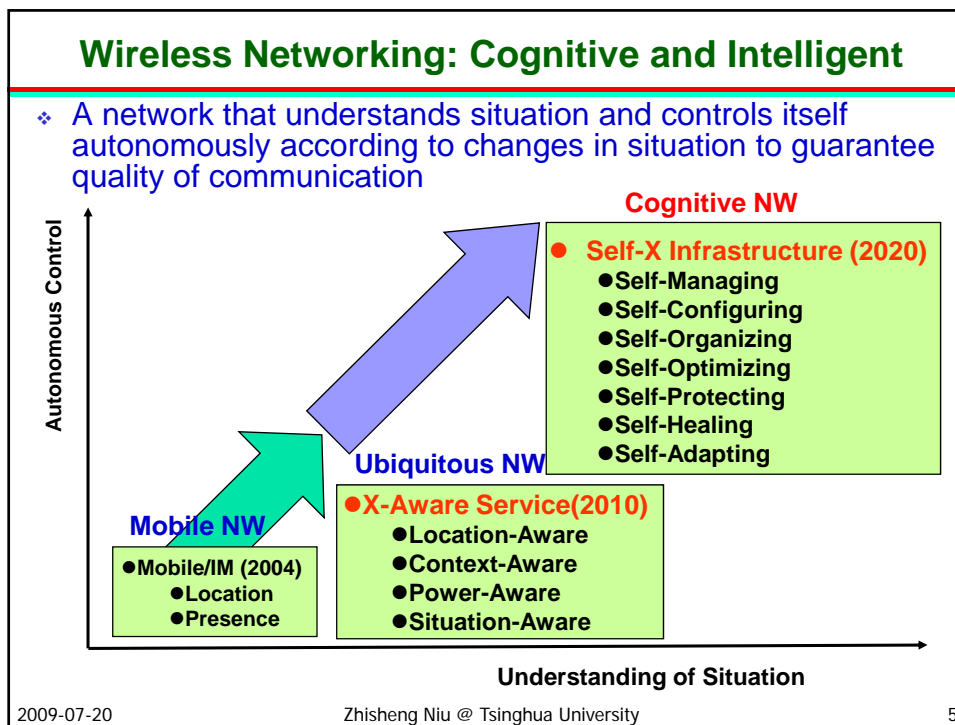
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Wireless Networking Everywhere





Wireless Networking: Collaborative and Cooperative

Convergence in the Core
(for load balance)

Convergence Between IP Transport Technologies (NGN)

Divergences of Access Media
(for always-best-connected)

Multiple Radio Networks

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MRN leads to Dense Wireless Networks

Mobile NW of 2G/3G (SRN) Mobile NW of 3G/4G (MRN, MIMO)

(few interference, noise-limited) (Many interference, interference-limited)

Interference

Interference

Dense Wireless NWs consume more powers

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Vision and Mission of NiuLab

NiuLab: Network integration for ubiquitous Linkage and broadband
 CHORUS: Collaborative Harmonized Radio Ubiquitous Systems

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Cross-Layer Design and Cross-NW Design

❖ **CLD - Opportunistic Scheduling**

- ❖ treats the channel variation as opportunity and try to exploit it

❖ **CND – Opportunistic Networking**

- ❖ Reduce competition and increase collaboration

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Major Research Topics in NiuLab

- ❖ **Multi-AP Diversity for Interference Avoidance**
 - Multiple AP Association with adaptive Physical Carrier Sensing range
- ❖ **Cooperative Diversity in Wireless Multihop Networks**
 - Collaborative and Opportunistic Scheduling (COS)
- ❖ **Triple-play Network Integration for always-best-connected**
 - Integrated Communication and Broadcast Networks (ICBN)
- ❖ **Multi-Dimensional Radio Resource Management**
 - Joint power and rate control in CDMA/OFDM/MIMO systems
 - Game-theoretical approach for multi-dimensional RRM
- ❖ **Power-efficient New Generation Networks**
 - Sleep-mode based power saving mechanism in WLAN and cellular systems

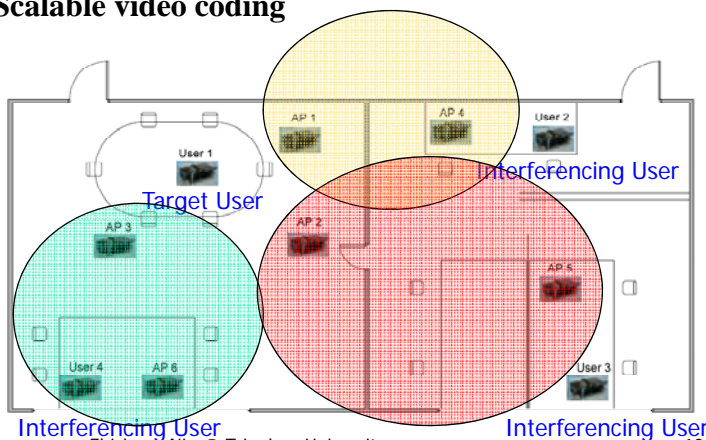
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Multi-AP Diversity in HD-WLAN

- ❖ **Solution**
 - **Multi-AP Association Architecture**
 - **Adaptive Physical Carrier Sensing range adjustment**
 - **Adaptive Scalable video coding**



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Dynamic Adjustment of AP Association

High-Density WLAN Multi-AP Research Platform

Testbed Layout

Index	Type	Ethernet IP	Wireless IP
0	AP_1	166.111.206.110	192.168.1.1
1	STA	166.111.206.114	192.168.1.2
2	AP_2	166.111.206.240	192.168.1.3
3	AP_3	166.111.206.110	192.168.1.4

Start Stop Show Log Record

Received Frames

STA	AP_1	AP_2	AP_3
PLR	48.8%	55.9%	42.2%
1	o	X	X
2	X	X	X
3	o	o	o
4	o	o	o
5	o	o	o

Uplink PLR Gain (relative: (P - P0) / P0)

Downlink Throughput / Mbps (RSSI-based: Red Band-usage-based: Blue)

Multi-AP Set	PLR	PLR_Gain	Downlink Main AP	Throughput_Gain
3 & 1	39.8%	18.4%	1	100.0%

AP	Last RSSI (dBm)	Throughput (Mbps)	Packet Loss Rate
3	-43	-0.223	48.6%
1	-38	7.362	9.7%

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Performance of Multi-AP Diversity

多点关联、分集接收

单点关联与传输

吞吐量 (Mbps)

时间 (s)

多点关联、分集发送/接收

多点关联、分集接收

吞吐量 (Mbps)

接入点个数

ICCC2008, Beijing

IEEE INFOCOM'07

IEEE SECON'08

IEEE Trans. Wireless Comm., April 2008

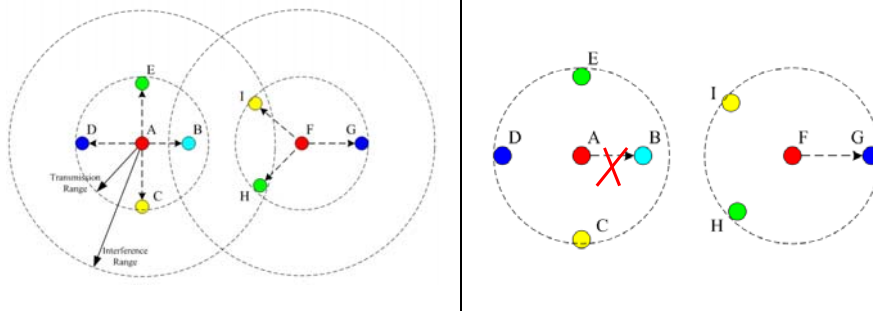
IEEE Trans. Wireless Comm., 2008 (accepted)

IEEE Trans. Wireless Comm., 2009 (accepted)

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Spatial Reuse in Wireless Multihop Networks

▪ If without cooperation,



If A chooses B, and then F chooses G by local scheduling, link A-B is corrupted by hidden terminal F in link F-G.

If a bandwidth requirement is assigned to the flow A-B, this link suffers a high collision probability induced by hidden terminal F.

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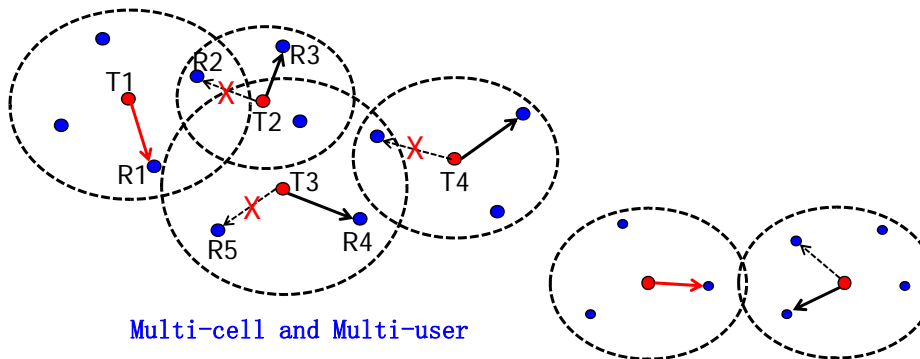
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Our Solution: QoS-Aware COS

❖ Cooperative & Opportunistic Scheduling with QoS Constraints

- Exploit **time-diversity** and **multiuser diversity** simultaneously, while providing **QoS guarantee**
- Through **cooperation**, some transmissions are deferred to favor some other links which have not achieved their QoS requirements



Multi-cell and Multi-user

Single-cell and Multi-user

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Features of the COS

- ❖ **The challenges of implementing the optimal scheduling in 802.11 based MANET**
 - **Exchanging parameters all over the network is impractical**
 - ✓ Use 2-hop information exchanging & average data rates
 - **Difficult to track the time-varying contention graph which is needed in the optimal scheduling**
 - ✓ Use average Local Contention Graph (LCG)
 - **To schedule a set of links in an ad hoc network in a deterministic pattern is not trivial**
 - ✓ Insert an extra interval (TIFS) into consecutive data transmissions

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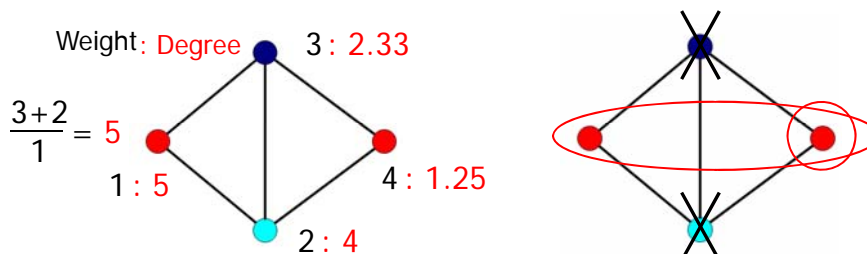
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A Distributed Heuristic Scheduling

Heuristic Algorithm:

- (1) select a minimal weighted degree vertex as a vertex in the weighted independent set S_m
- (2) delete the vertex and all of its neighbors from the graph
- (3) repeat this process for the remaining subgraph until the graph becomes empty.

$$\text{Weighted Degree (WD): } d_w(v, G) = \frac{w(N_G(v))}{w_v}$$

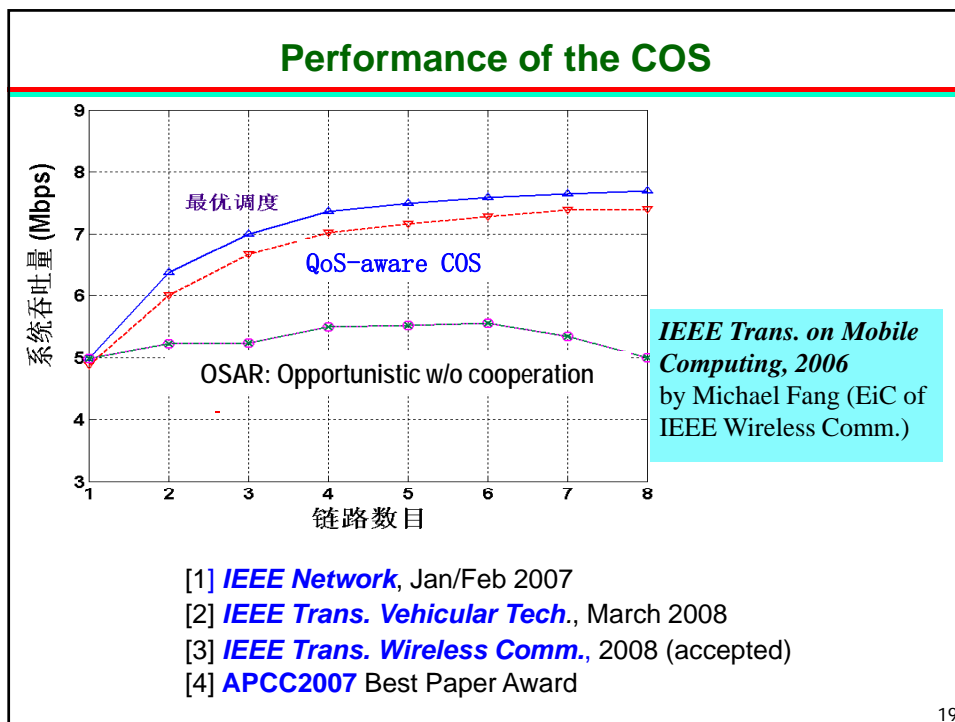


Exchange weight and WD among neighboring links

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Integrated Comm and Broadcast NW

- ◆ Existing Approaches are no more Efficient
 - ◆ Higher frequency narrows down the cell size and therefore hard to support high mobility due to frequent handovers and indoor reception due to attenuation. Also may cause serious co-channel interferences
- ◆ Should Exploit Broadcasting Nature of Broadcast NW
 - Internet Contents also follow Power Law Distribution
 - ✓ Most users visit fewer websites
 - BC-NW is in nature **broadband, high-volume, wide and seamless** coverage, and **reliable** information delivery systems **without congestion**
 - Traffic load of Internet can be dramatically reduced if we can push most of the Internet and video contents to mass users by broadcast

Broadcast Channels are Available

移动通信系统(Mobile Communication Systems)			
	空中接口 (Air Interface)	带宽 (Bandwidth)	传输速率 (Data Rate)
MBMS (3GPP, WCDMA)	WCDMA	5MHz	32×64kbps (with 2 Rx antennas)
BCMCS (3GPP2, CDMA1xEVDO)	EVDO	1.25MHz	409.6Kbps (with 2 Rx antennas)
TD-MBMS (TD-SCDMA)	TD-SCDMA	5MHz	128-192kbps (with single timeslot)
地面广播系统(Terrestrial Broadcast Systems)			
中国数字电视地面传输标准 DTMB	地面移动多媒体广播 TMMB	中国移动多媒体广播电视 CMMB	

北京奥运期间进行了TD-MBMS手机电视业务试运行
(A field trial mobile TV reception service based on TD-MBMS was provided during Beijing Olympic)

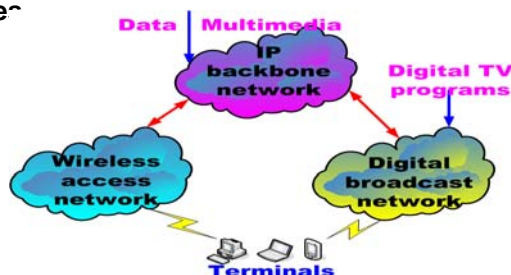
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A New Approach: ICBN

- ❖ 广播网络本质上是**宽带、大容量、和广域覆盖的**，且**没有拥塞**
(BC-NW is in nature *broadband, high-volume, wide coverage*, and in addition *without congestion*)
- ❖ **数字广播网络非常适合于非对称及多播业务**
(BC-NW is also very suitable for *asymmetry and P-mP traffic*)
- ❖ **但是，广播网络无法实现双向业务**
(BC-NW can not realize *bi-directional communication*)
- ❖ **广播网络的数字化使得通信与广播网络融合成为可能**
(Digitalization of BC-NW make the *integration possible*)

[1] Z. Niu, L. Long, J. Song, C. Pan,
"A new paradigm for mobile
multimedia broadcasting based on
Integrated Communication and
Broadcast Networks", *IEEE
Communications Magazine*, July 2008



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Key Issues of ICBN

- ❖ **单向广播信道不适合于数据及压缩视频广播**
(Unidirectional broadcast NW is not good for data/compressed video broadcasting)
- ❖ **带宽受限、大延迟且高误码率的反向信道严重影响TCP性能**
(Narrowband, large RTT and error-prone return channel deteriorate the TCP throughput)
- ❖ **基于ACK的ARQ机制会导致反向信道严重拥塞**
(ACK-based ARQ scheme is no more efficient)
- ❖ **异构网络的协同管理**
(OAM in communication NWs and broadcast NWs are quite different)
- ❖ **通信与广播融合业务的动态资源调度**
(Bandwidth allocation of integrated CS and BS)

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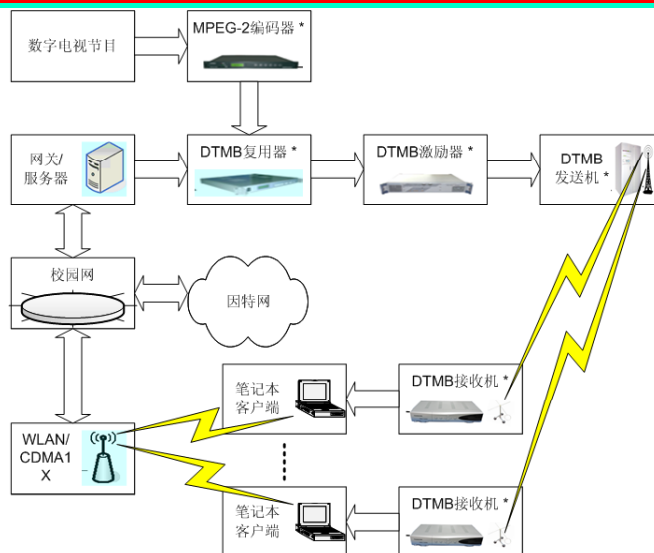
Our Contributions

- ❖ **提出了基于通信与广播融合网络的移动多媒体服务新模式**
(A New Paradigm for Mobile Multimedia Services by Integrated Communication and Broadcast Network)
- ❖ **设计了SNDU高级链路层协议并对协议性能进行了分析**
(A New SNDU Layer for Integrated Multimedia Services)
- ❖ **提出了一种选择性NAK机制，解决了ACK泛滥的问题**
(A New Selective-NAK Scheme to solve the ACK Flooding)
- ❖ **提出了一种层次化可靠组播机制**
(A reliable multicast scheme by local proxy and neighbor terminals to improve system throughput)
- ❖ **针对通信与广播融合网的特点对TCP协议进行了改进**
(A modified TCP protocol for ICBN)
- ❖ **搭建了演示平台、验证了所提算法的有效性**
(A Testbed by combining DTMB and CDMA1X)

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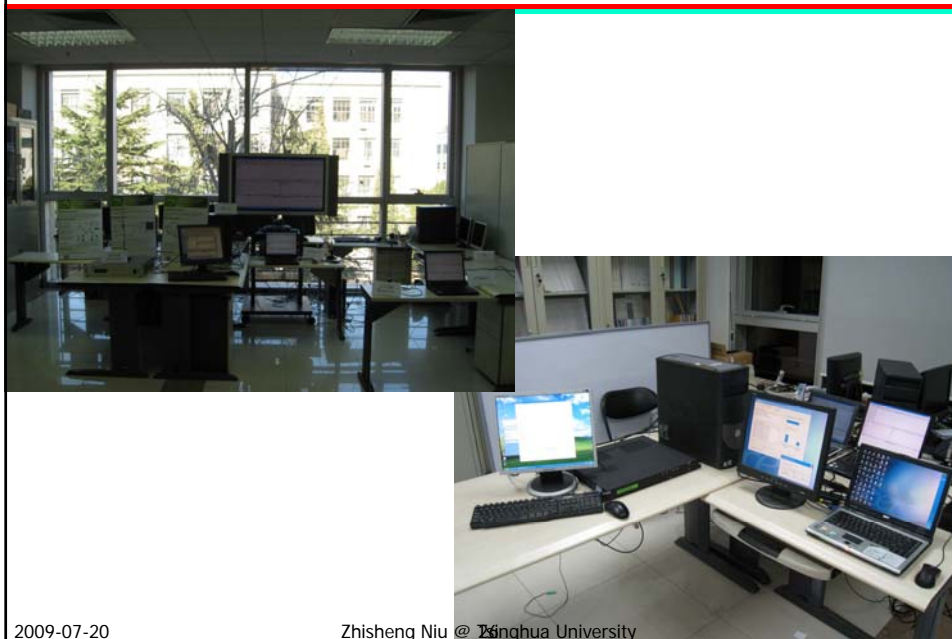
Testbed of ICBN by DTMB and CDMA1X



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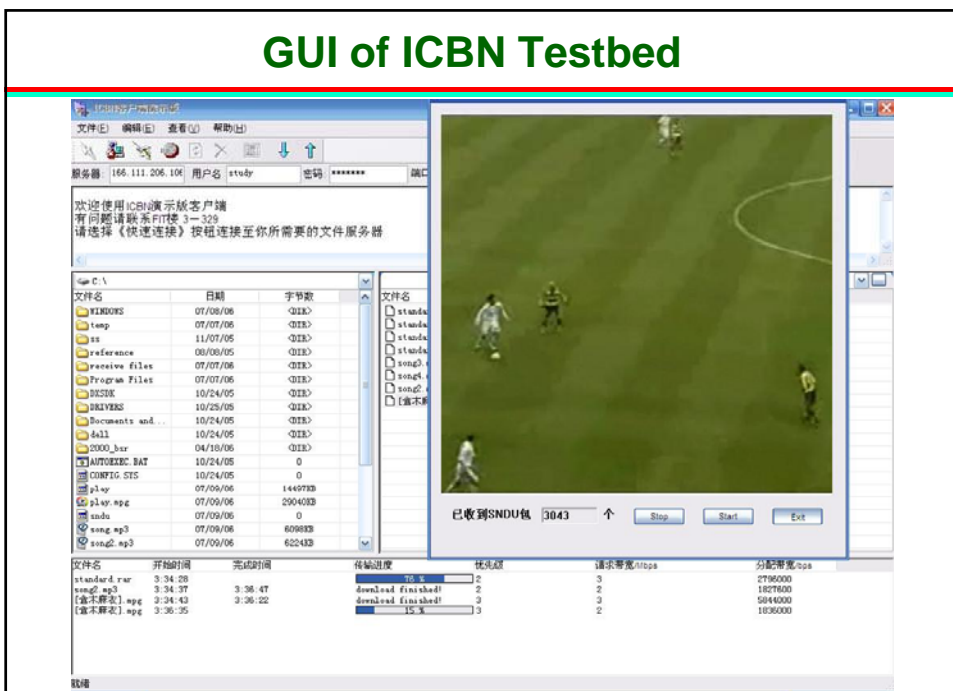
Testbed for ICBN with Selective NAK based H-ARQ



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GUI of ICBN Testbed



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Demo for File Downloading via ICBN



On-demand file downloading while enjoying DTV programs either in a separate channel or in the same channel

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Further Reading

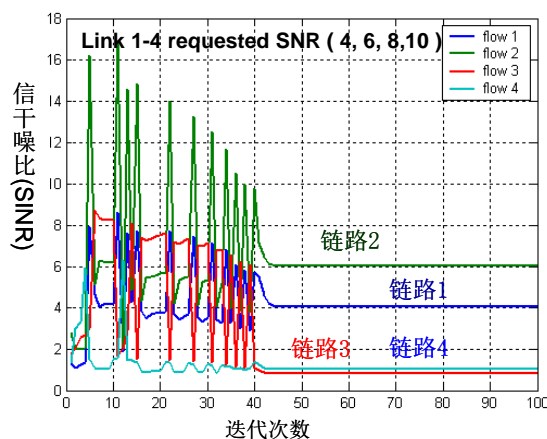
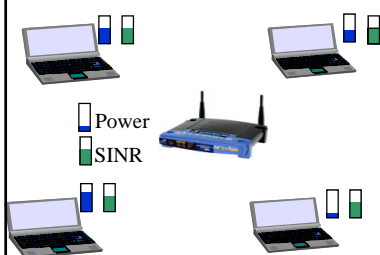
1. Z. Niu, L. Long, J. Song, C. Pan, "A new paradigm for mobile multimedia broadcasting based on Integrated Communication and Broadcast Networks", **IEEE Communications Magazine**, July 2008
2. L. Gu, Z. Niu, J. Lv and H. Yoshiuchi, "An NAK-based Hierarchical ARQ Scheme for Reliable Data Multicast in Integrated Communication and Broadcast Networks", **APCC'08**, Tokyo, Japan, Oct. 2008
3. L. Long, Z. Niu, B. Zhu, "A hybrid DMB-T and WLAN network for broadband wireless access services," **IEEE WCNC'07**, HongKong, China, Mar. 2007.
4. L. Long, A. Ramdorai, and Z. Niu, "Error modeling and throughput analysis in ICBN", **APCC'07**, Bangkok, Thailand, Oct. 2007.
5. G. Miao, Z. Niu, "Bandwidth Management for Mixed Unicast and Multicast Multimedia Flows with Perception Based QoS Differentiation", **IEEE ICC'06**, Istanbul, Turkey, 11-15 June, 2006
6. G. Miao, Z. Niu, "Satisfaction Oriented Resource Management in Integrated Internet and DVB-T Network Providing High Mobility Broadband Access Services", **IEEE Globecom'05**, St. Luis, USA, 28 Nov.-2 Dec. 2005
7. G. Miao, Z. Niu, "Profit Oriented Multichannel Resource Management of Integrated Communication and Broadcast Networks", **IEEE Trans. Broadcasting**, Vol.51, No.4, pp.530-537, Dec. 2005

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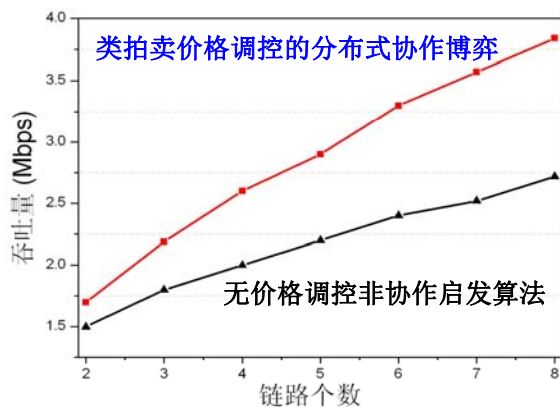
Multi-Dimensional RRM

A Game Theoretical Approach with Auction-like Pricing



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Performance of our Auction-like Pricing Game



IEEE Trans. on Wireless Commun., 2004
by A. Ephremides

IEICE Trans. Commun.

(2004.5, 2004.8, 2005.9, 2005.12, 2006.6, 2006.6)

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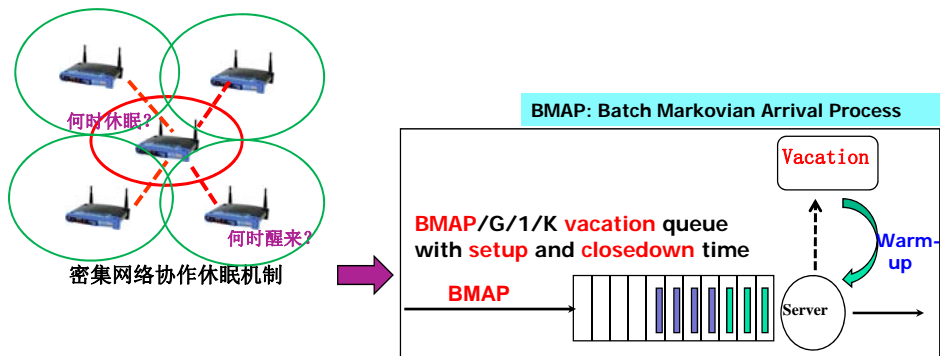
- [1] "Pareto Improvement for Radio Resource Control under Incomplete Channel Information: A Game-Theoretical Approach", *IEICE Trans. Commun.*, May 2004.
- [2] "Optimizing Radio Resource Allocation in Multimedia DS-CDMA Systems Based on Utility Functions", *IEICE Trans. Commun.*, Aug. 2004.
- [3] "A Game-theoretical Power and Rate Control for Wireless Ad Hoc Networks with Step-up Price", *IEICE Trans. Commun.*, Sep. 2005.
- [5] "An Efficient Rate and Power Allocation Algorithm for Multiuser OFDM Systems", *IEICE Trans. Commun.*, Dec. 2005
- [4] "Adaptive Power Control in Multi-cell OFDM Systems: A Noncooperative Game with Power Unit based Utility", *IEICE Trans. Commun.*, June 2006.
- [6] "Joint transmit rate, power and antenna allocation for MIMO systems with multimedia traffic", *IEICE Trans. Commun.*, June 2006

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Collaborative Sleeping Mechanism



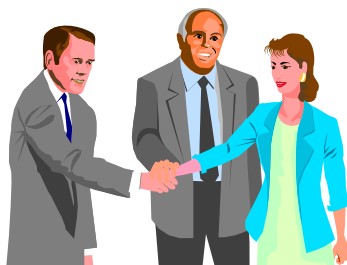
- [1] Z. Niu, T. Shu, Y. Takahashi, "A Vacation Queue with Setup/Close-down Times and Batch Markovian Arrival Process", *Performance Evaluation*, 2003
- [2] Z. Niu, Y. Takahashi, "A Finite-Capacity Queue with Exhaustive Vacation and Setup/Close-down Times and Markovian Arrival Processes", *QUESTA (Queueing Systems: Theory and Applications)*, 1999

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Thank You and Future Contact



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