Additional Work

- JSCC (L. Kondi, F. Ishtiaq, and A. K. Katsaggelos, "Joint Source-Channel Coding for Motion-Compensated DCT-Based Scalable Video," *IEEE Trans. IP*, vol. 11, pp. 1043-1052, Sept. 2002)
- Data Rate Adaptation and Scheduling (C. Luna, Y. Eisenberg, R. Berry, T. Pappas, A. K. Katsaggelos, "Joint Source Coding and Data Rate Adaptation for Energy Efficient Wireless Video Streaming", *IEEE JSAC*, pp. 1710-1720, Dec. 2003)
- DiffServ (F. Zhai, C. Luna, Y. Eisenberg, R. Berry, T. Pappas, A. K. Katsaggelos, "Joint Source Coding and Packet Classification for Real Time Video Transmission over DiffServ Networks", *IEEE Trans. Multimedia*, vol. 7, issue 4, 716-726, August 2005).
- Hybrid (FEC, retransmission) Rate Control (F. Zhai, Y. Eisenberg, T. Pappas, R. Berry, A. K. Katsaggelos, "Rate Distortion Optimized Hybrid Error Control for Real-Time Packetized Video Transmission", *IEEE Trans. Image Processing*, vol. 15, issue 1, 40-53, January 2006).
- Hybrid wired/wireless transmission (F. Zhai, Y. Eisenberg, T.N. Pappas, R. Berry, and A.K. Katsaggelos, **"Joint Source-Channel Coding and Power Adaptation for Energy Efficient Wireless Video Communications,"** *Signal Processing: Image Communications*, February 2005.)
- Object-based Encoded Video Transmission (H. Wang, F. Zhai, Y. Eisenberg, and A.K. Katsaggelos, **"Cost-Distortion Optimized Unequal Error Protection for Object-based Video Communications,"** *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 15, issue 12, 1505-1516, December 2006; H. Wang, S.A. Tsaftaris, and A.K. Katsaggelos, **"Joint Source-Channel Coding for Wireless Object-based Video Communications Utilizing Data Hiding,"** *IEEE Trans. Image Processing*, vol. 15, issue 8, 2158-2169, August 2006.)
- FGS Scalable Video Transmission *(F. Granelli, C.E. Costa, and A.K. Katsaggelos, **"A Study on the Usage of Cross-Layer Power Control and Forward Error Correction for Embedded Video Transmission over Wireless Links,"** Advances in Multimedia, special issue on Cross-layer Optimized Wireless Multimedia Communications: Hindawi, Article ID 95807, 2007)*
- Additional Work:
  - Z. Li, F. Zhai, and A.K. Katsaggelos, **"Joint Video Summarization and Transmission Adaptation for Energy-Efficient Wireless Video Streaming,"** *EURASIP Journal on Advances in Signal Processing, special issue on Wireless Video*, vol. 2008, Article ID 657032; 11 pages, 2008.
  - K.E. Zachariadis, M.L. Honig, and A.K. Katsaggelos, **"Source Fidelity over Fading Channels: Performance of Erasure and Scalable Codes,"** *IEEE Trans. on Communications*, July 2008.
  - J.W. Huang, Z. Li, M. Chang, and A.K. Katsaggelos, **"Joint Rate Control and Scheduling for Wireless Uplink Video Streaming,"** *Journal of Zhejiang University, Science A*, vol. 7, issue 5, 801-810, May 2006.
  - J. Huang, Z. Li, M. Chiang, , and A.K. Katsaggelos, **"Joint Source Adaptation and Resource Allocation for Multi-User Wireless Video Streaming,"** *IEEE Trans. Circuits and Systems for Video Technology*, vol. 18, issue 5, 582-595, May 2008.

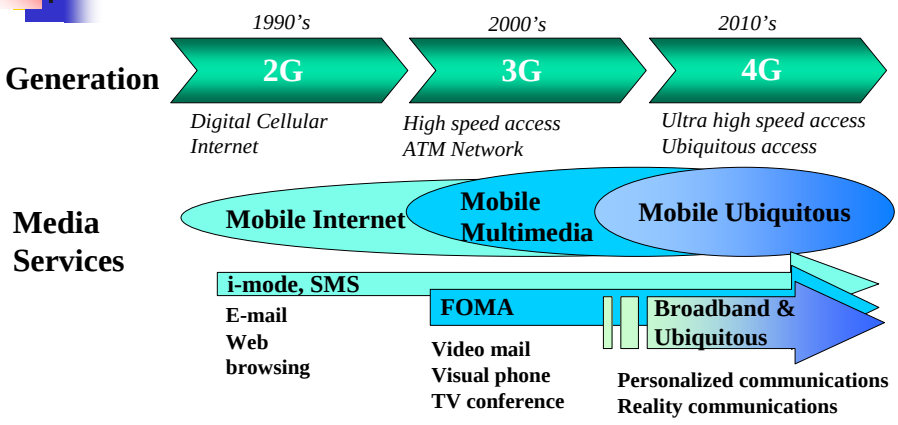
Closing Remarks

- Rich topic at the intersection of multimedia signal processing, communications, and networking
- Increasing number of applications
- Touched the tip of the iceberg

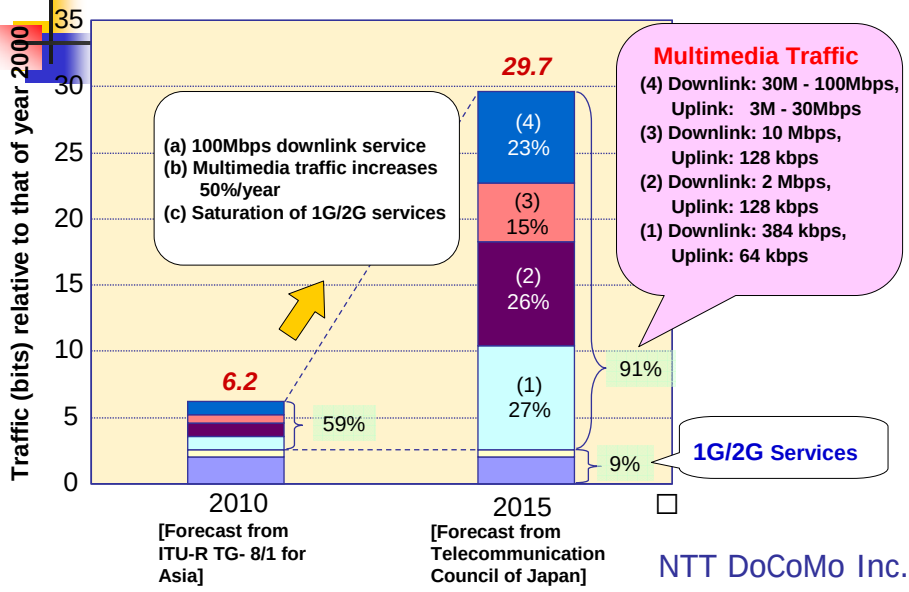
Future Research Directions

- Distributed Multimedia Communications
  - Resource allocation for video streaming over multi-hop networks
    - mobile ad hoc networks
    - Mesh networks
    - Sensor networks
  - Multi-user, up- and down-link
  - Hybrid networks
  - P2P
- More sophisticated
  - Concealment methods
  - Distortion metrics, utility functions
- Scalable coding, MDM
- Data hiding, authentication
- Power dissipation

Network Evolution



Forecast on Future Multimedia Traffic



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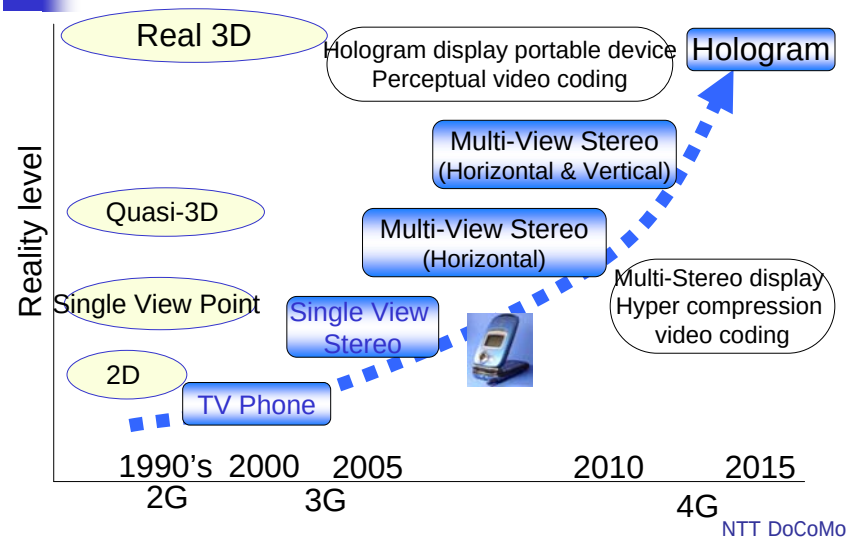
Reality Visual Communications



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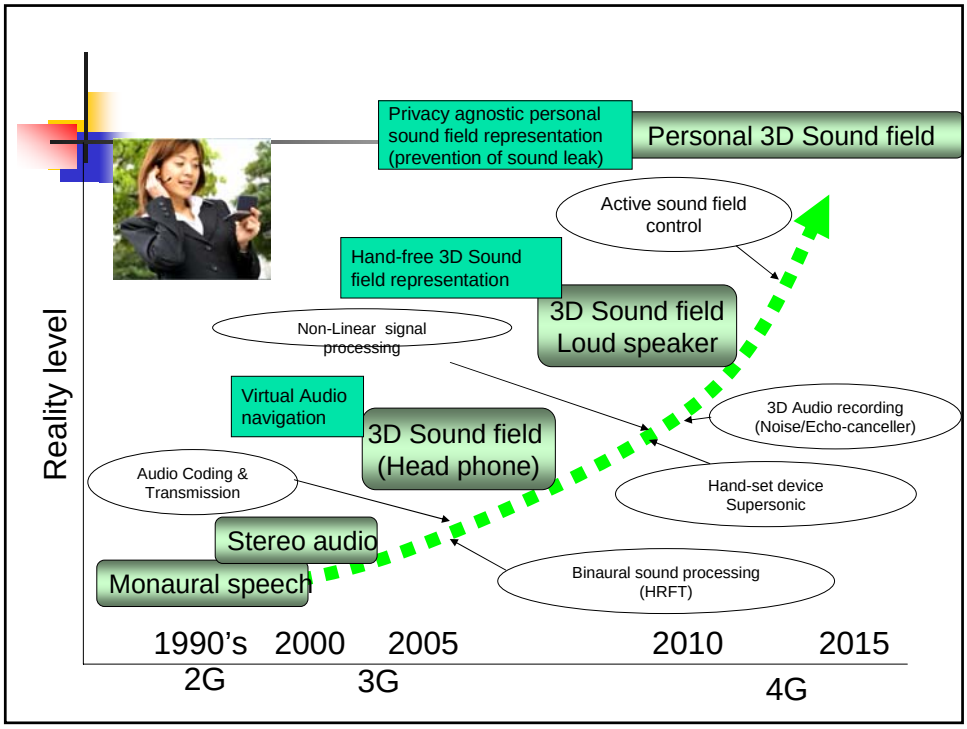

Requirements for Future Mobile Networks

Media	Transmission speed	Delay	Connection Latency	Terminal capabilities
Speech/ 3D Audio	< 1 Mbps	<50ms	<1sec	• 3D sound field control • High efficiency loud speakers
Video/ 3D video	10Mbps (2D video) ~ 30Gbps (3D video)	<50ms	<1sec	• Real time hologram
Enhanced Reality	< 1Mbps	<< 50ms Should be predictable	N/A	•Eyeglass display •3D and multimodal UI
Five senses communications	< 1Mbps	<50ms	N/A	•Five sense sensors
Tele-existence	<10Mbps (Robotic I/F) < 1Gbps (Virtual avatar) < 100Mbps (Alter-ego existence)	< 10ms < 30ms < 5ms (Small and known jitter)	<1sec	• Alter-ego robot

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Future

Predictions are hard, especially about the future

Niels Bohr

The best way to predict the future is to invent it

Alan Kay

I never think of the future, it comes soon enough

Albert Einstein

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