

# From Wireless Voice to Wireless Video

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## OUTLINE

- Wireless Evolution
- Giga-bit Wireless

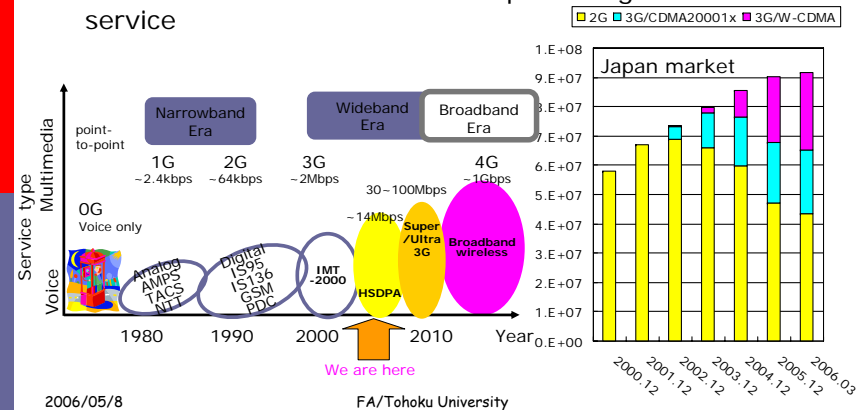
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# Wireless Evolution

- Demands for broadband wireless services (internet related) are increasing. Even ~14Mbps data rate capability of 3.5G will sooner or later become insufficient
- Visual communications will be a promising wireless service

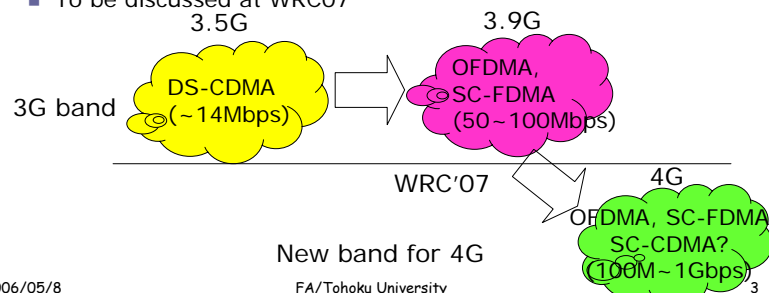


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## Before 4G, there will be 3.9G

- 3.9G will use 3G band
  - No available bandwidth of 100MHz (a hot matter of WRC-07)
  - Present 3G bandwidth (1.25~20MHz) is used to provide much faster rate data services
  - Target: 100Mbps for downlink, 50Mbps for uplink
- 4G will be an enhanced 3.9G
  - New frequency band will be used
  - To be discussed at WRC07



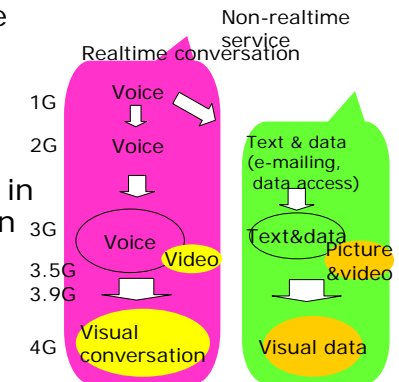
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## What Is a Killer Application in 4G?

- It is quite difficult to predict which services will become popular in the coming 10 years
  - However, it is no doubt that Internet related services will dominate in 4G
- Another promising service in 4G is visual communication
  - Earlier generations of communication networks provided voice services only
  - Our natural communication way is to speak/hear while looking
  - **Visual communication everywhere** will be one of important services



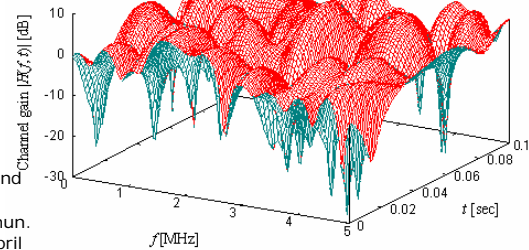
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# Fading Problem

- Channel randomly varies both in frequency and in distance. Challenge is to transmit data at high speed (close to 1 Gbps) with high quality under such a severe doubly selective fading environment
  - Frequency-domain equalization (FDE) is an important technique [Adachi et al]



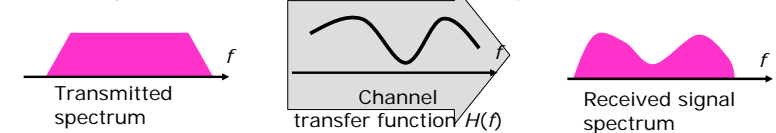
■ F. Adachi, D. Garg, S. Takaoka, and K. Takeda, "Broadband CDMA techniques," IEEE Wireless Commun. Mag., Vol. 12, No. 2, pp. 8-18, April 2005.

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16-path exponential profile, delay factor of 1.0 dB, time delay separation of 150ns, carrier frequency of 5 GHz, moving speed of 4km/h  
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- Common belief
  - DS is a technique for 3G
  - MC has been considered the best candidate for the wireless access to overcome the frequency selectivity of the channel
- Single-carrier transmission
  - Signal distortion causes severe inter-symbol interference (ISI)



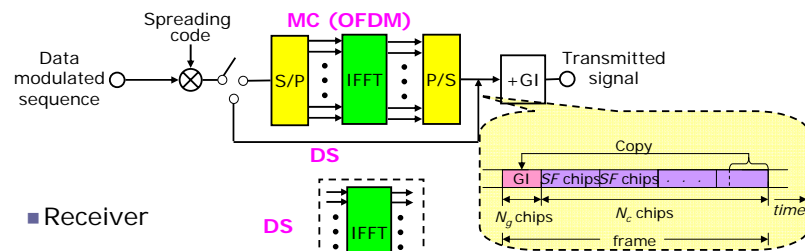
- Multi-carrier transmission
  - A number of narrowband orthogonal subcarriers is used to transmit high speed data in parallel
  - Each subcarrier experiences frequency nonselective fading and hence ISI is not produced



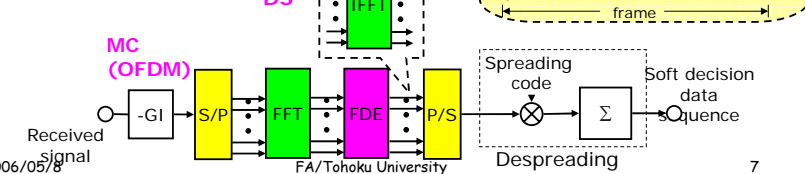
# FDE Is Powerful

- With FDE, both DS- and MC-CDMA can exploit channel frequency-selectivity to improve the performance
- Transmitter/receiver structure is similar

### Transmitter



### Receiver



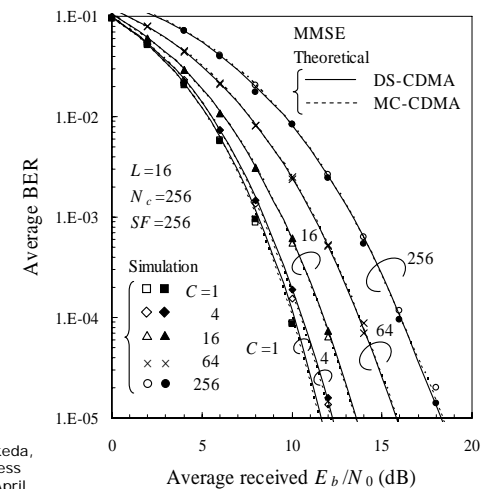
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- Multi-user case ( $C > 1$ )
- Both CDMA provide almost the same BER performance for the downlink (base-to-mobile)

- Multi-user interference (MUI) is predominant cause of errors than self interference



F. Adachi, D. Garg, S. Takaoka, and K. Takeda, "Broadband CDMA techniques," IEEE Wireless Commun. Mag., Vol. 12, No. 2, pp. 8-18, April 2005.

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## CDMA Air-interface Is Flexible

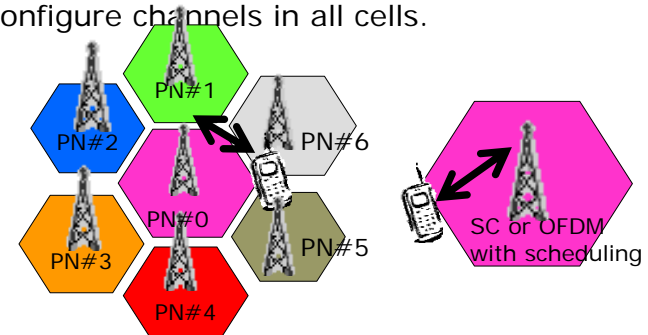
- The use of OVSF spreading codes\* allows construction of spread and non-spread systems for real time and non-real time services
- Cellular ( $SF > 1$ )
  - Simultaneous real time and non-real time services with relatively low data rate per user
- Hot spot areas ( $SF = 1$ )
  - Similar to present WLAN
  - Non-real time services with very high data rate per user are provided by random TDMA system with appropriate scheduling.
  - An  $SF = 1$  system can be extended to a cellular system with the aid of fast selection of transmit cell and adaptive antenna array.

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\*F. Adachi, M. Sawahashi, and K. Okawa, Electron. Lett., vol. 33, pp. 27-28, Jan. 1997.

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- Different PN scramble codes are assigned to different cells to distinguish different cells.
- The same set of OVSF codes is used to configure channels in all cells.



(a) Cellular system ( $SF > 1$ ) (b) Isolated-cell system ( $SF = 1$ )

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F. Adachi, "Challenges for broadband mobile technology," Proc. 12th International Conference on Antennas & Propagation (ICAP 2003), pp. 1-4, Exeter, U.K., Apr. 2003.

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## Power Problem

- Links for 100Mbps~1Gbps are severely power-limited
  - Peak power is in proportion to " $f^{2.6} \times \text{transmission rate}$ " [Hata]. Peak transmission power for 100Mbps@5GHz is about 135,000 times that of 8kbps@ 2GHz, e.g., 1W -- > 135kW. Obviously, this cannot be allowed
  - Cell size should be reduced by about 29 times (e.g., 1,000m → 34m cell)
- Fundamental change necessary in wireless access network architecture
  - Multi-hop technique will be a key technique to solve the power problem [Kudoh&Adachi]

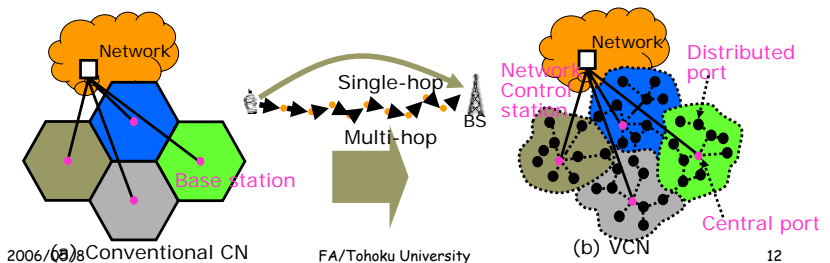
- M. Hata, "Empirical formula for propagation loss in land mobile radio services", IEEE Trans. Veh. Technol., VT-29, pp. 317-325, 1980.
- E. Kudoh and F. Adachi, "Power and Frequency Efficient Wireless Multi-hop Virtual Cellular Concept," IEICE Trans. Commun., Vol.E88-B, No.4, pp.1613-1621, Apr. 2005. FA/Tohoku University

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## Single-hop to Multi-hop

- Antennas everywhere, which is an entrance into the network, can solve the power problem
- One such a realization is multi-hop virtual cellular network (VCN)
  - Many distributed wireless ports with a central port as a gateway to the network
  - Mobile terminal and central port are connected using wireless multi-hop technique
- VCN is suitable for non-real time packet communication



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(a) Conventional CN

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(b) VCN

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## Conclusion

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- Next generation network is a broadband packet network and requires Giga-bit wireless technology of ~1Gbps capability
- Killer application: Wireless visual communications?
- There are lots of interesting and important research topics before the born of 4G wireless systems
  - Giga-bit wireless technology: Broadband CDMA, Hybrid ARQ, MIMO, etc
  - High efficient video coding technique
  - Multihop technique in cellular systems