

# Autonomous Spectrum Management – A vision for 4G

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# Perspectives on Spectrum Management

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- ❑ Currently: Two types of spectra for wireless access networks:
  - Unlicensed (WiFi) -> large bandwidth -> less focus on spectral efficiency
  - Licensed (Cellular) -> smaller bandwidth -> must be spectral efficient
- ❑ Characteristics:
  - Cellular: Fixed allocation, rigid deployment, good interference management, somewhat regular layout, wide area coverage.
  - WiFi: Low cost AP, flexible deployment, user driven deployment, organic growth, irregular cells, hot spot coverage, interference management?, spectral efficiency?
- ❑ There has been requirement for flexible ways to manage the spectra.
  - Spectrum pooling
  - Cognitive radio
- ❑ New network design philosophy:
  - Key is flexible low cost deployment and management
  - Intelligent Interference management
  - Autonomous infrastructure deployment, **autonomous spectrum management (ASM)**

# Wireless System Evolution

- Cellular Systems
  - 1G, 2G, 3G, 3G/LTE, ...
  - Extension of telephone network to mobile
- IEEE 802.11 (WiFi)
  - a/b/g/e/n versions
  - Extension of LAN's to wireless
  - Infrastructure mode
  - Ad-hoc mode
  - Extension of Internet access to wireless
- IEEE 802.16 (WiMax)
  - Extension of ATM to wireless
  - Wireless video transmission

# Evolution 1G -> 3G

- Evolution from 1G to 3G stressed higher bit rates and greater network capacity for a given amount of spectrum.
- Centrally planned network
- More or less equal capacity per cell.
- More or less regular cellular structure.
- Regular cells, micro cells, pico cells
- Cost of base station/access point deployment is a key issue.

# 4G Themes

- Initially no clear set of goals for 4G
- Various attempts to combine different technologies: 3G, WiFi, WiMax => convergence
- Some indications that the main issue is not some notion of network capacity but different networking/deployment paradigms
- Re-evaluate all assumptions about cellular systems: FDD/TDD, non-symmetric allocation of spectrum, cells sizes, base station/terminal/relays, very high data rates, etc ..

# Future Networks

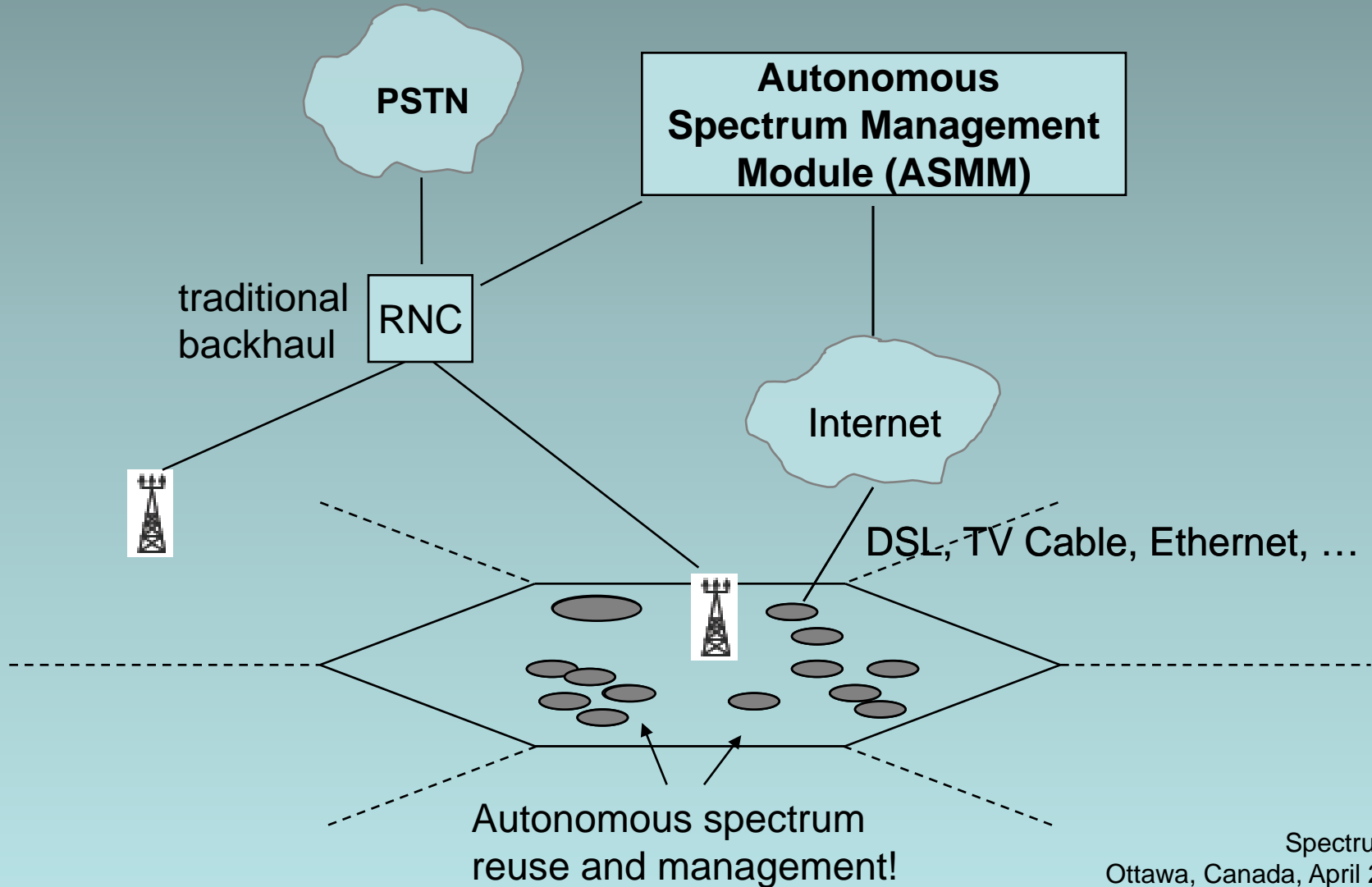
- A network architecture with the characteristics of WLAN's in the sense that it allows inexpensive ad-hoc deployment of infrastructure.
- A network architecture with the characteristics of 3G: channelized, ubiquitous, interference control, spectral efficiency
- Seamless inter-operation with wide-area backbone network (cellular-like)
- Single unified air-interface and access point inter-connection network based on IP
- Ease of deployment and management

# Autonomous Spectrum Management in Cellular Networks

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- Autonomous spectrum management enables flexible reuse of the licensed spectrum in space.
- Cellular infrastructure base stations are deployed by network users in an autonomous manner.
- Organic improvement of spectral efficiency
- Network interference is centrally optimized by software control.
- Organic integration of hotspot and wide-area coverage
- Robust air interface with intelligent re-configurability
- Network self-management with autonomous resource allocation

# Autonomous System Architecture for 4G Cellular Networks

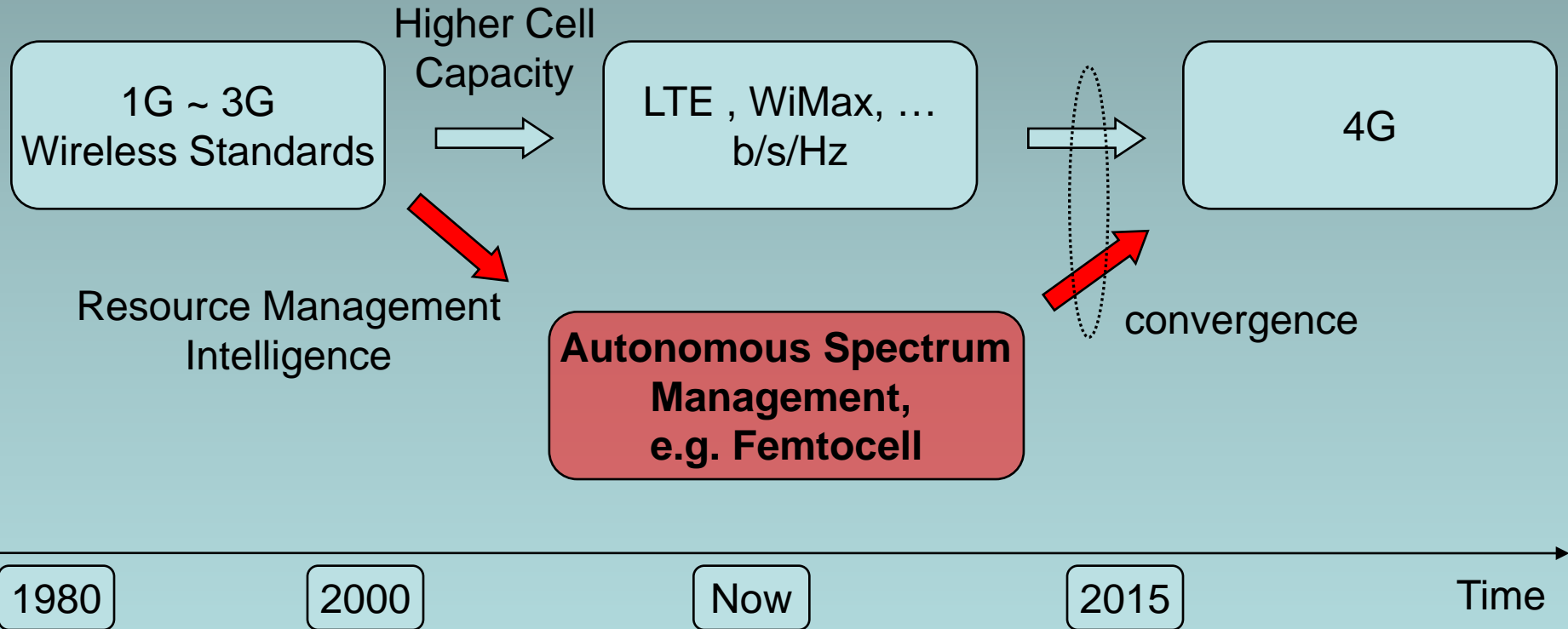


# Autonomous Infrastructure Networks

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- **Large base station**
  - the regular base station deployed by the network operator with full engineering capability. Frequency reuse, antenna tilting angle, pilot power etc have to be carefully configured for public user access.
- **Small base station/femtocell**
  - the small infrastructure equipment autonomously deployed by network users. Interference management is optimized by network control server. Current 3G interfaces may require certain modification in order for autonomous network configuration.
- **Autonomous spectrum management module (ASMM)**
  - the intelligent control module for autonomous spectrum management. The module works as the brain of the network which autonomously reconfigures RF radio and optimize the resource allocation.

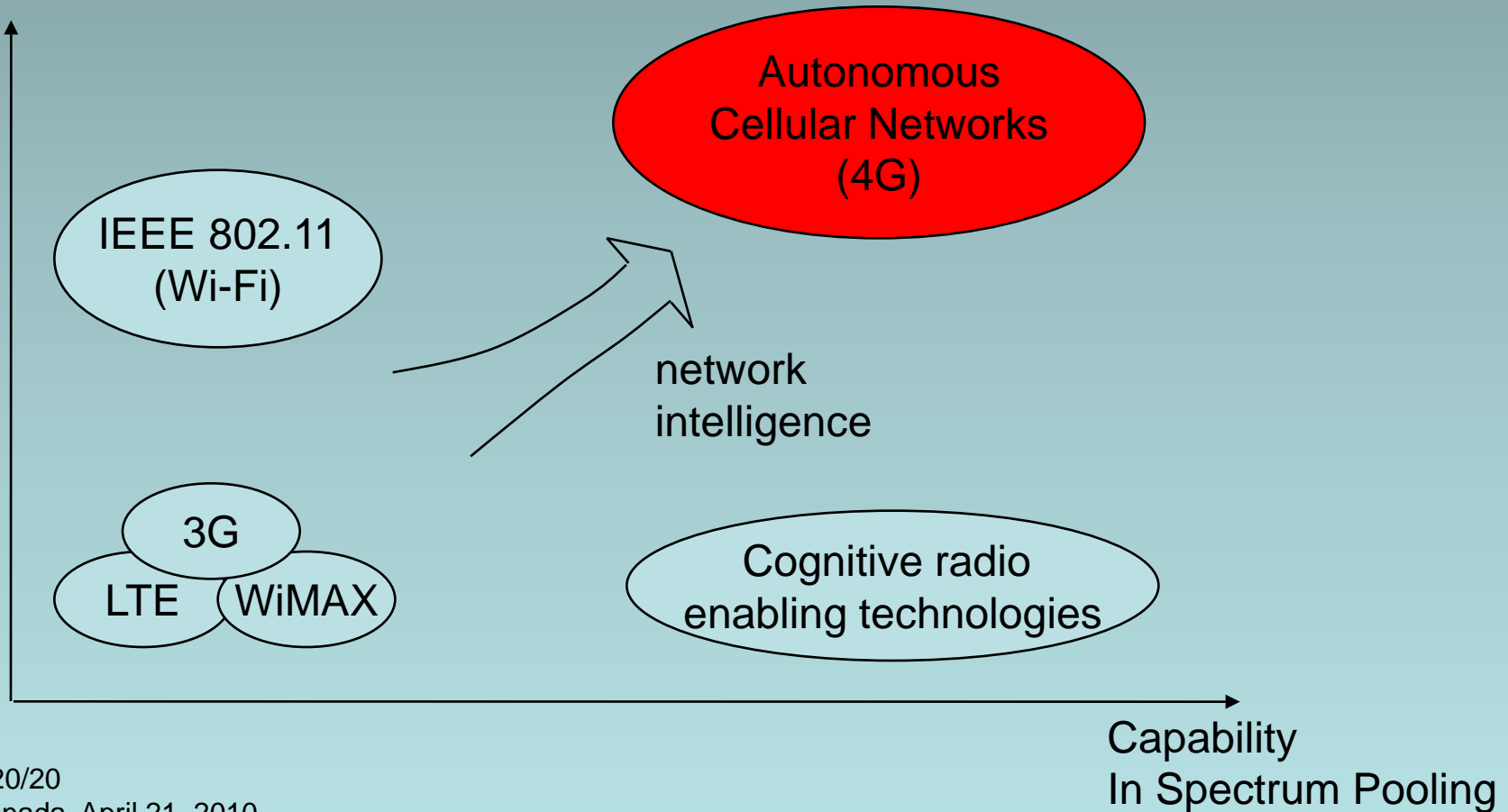
# Cellular Evolution to 4G



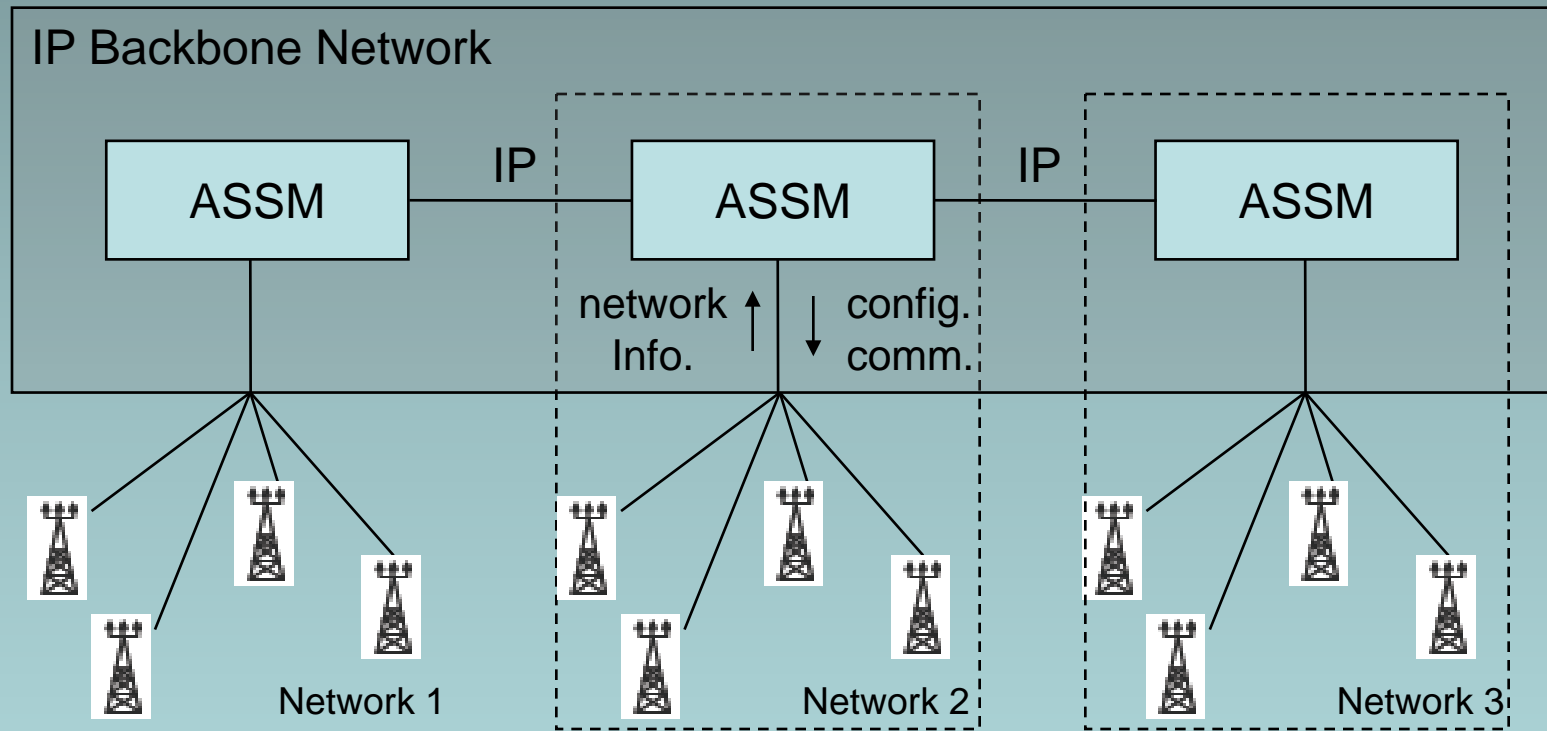
# 4G Enabling Perspective with ASM

Flexibility

In Spectrum Spatial Reuse



# Autonomous Spectrum Pooling



- ASSM servers for different wireless networks are interconnected through IP.
- Spectrum allocation is autonomously decided based on the environment information of each network and exchanged across different ASSM servers.
- Commands are sent from ASSM to infrastructure BS for automatic configuration.

# Different Approaches to Broadband

- Current approach
  - Great emphasis on squeezing out more b/s/Hz with new transmission methods: 64 QAM, MIMO. Higher QAM => diminishing returns. Higher MIMO => problem with channel (violates the physics). If the goal is really higher rates then go to optical!
  - High power BS with many antenna elements, e.g. proposed 8 elements in base, and 4 elements in terminal. Complex installation.
- New approach
  - It is not b/s/Hz! That matters. It is b/s/Hz/cell.
  - Deploy more BS/APs.
  - Keep the BS/APs simpler with a good set of configuration parameters.
  - Lower power.
  - Focusing on the correct configuration parameters and ASM approaches => greater returns
  - Strategy for deployment and management becomes the key

# Summary

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- ASM in 4G networks enables spectrum pooling in an autonomous manner.
  - ASM leverages the benefits of the following technologies:
    - Cellular: infrastructure-based for rigorous RF optimization
    - Wi-Fi: ad hoc based for low-cost infrastructure deployment
    - Cognitive radio: SDR based for improved spectrum visibility
  - Software-based network management with easy updating of control algorithms
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- Autonomous Infrastructure Network Research at UofT:
    - Autonomous interference management
    - Autonomous cellular network coverage optimization
    - Autonomous cellular resource allocation
    - OFDM Autonomous network configuration

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