Scarcity of Licensed Spectrum for Mobile

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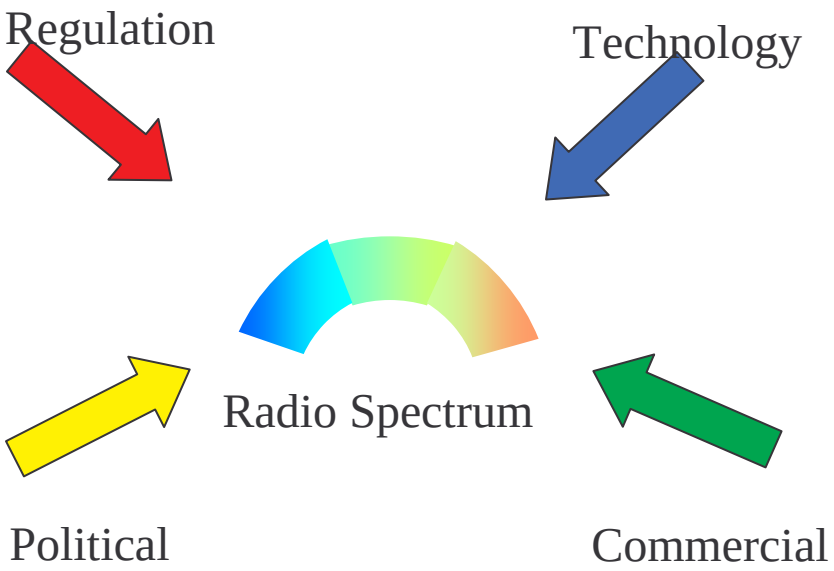
Structure

- Framework of Theory and Practice
- Spectrum management in general
- Service and Technology evolution
- Estimating Spectrum needs: One simple example
- Next Steps
- Regulative pitfalls and Flexibility in Regulation
- Summary

Framework

- Factors Impacting availability of Radio Spectrum
- Regulation
  - Right, Efficient and Effective decisions
- Political
  - Governments or companies looking for political reasons to use spectrum inefficiently
- Technology
  - Efficient use of modern technologies
  - Quality of Implementations
- Commercial
  - Pricing of spectrum
  - License terms



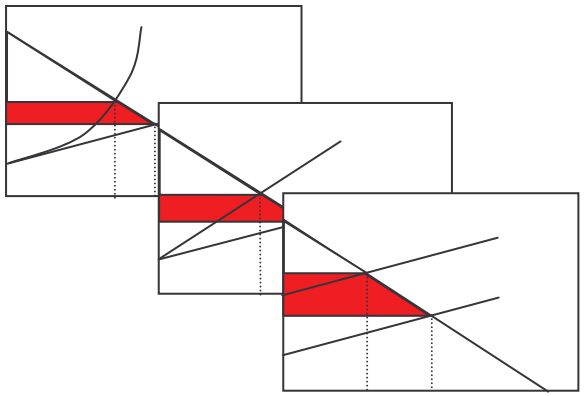
Theory and practice

- Various theories may be used to estimate the scarcity of Radio Spectrum

- Promote experimenting and innovation => Real Option
- Promote Social Welfare => Utility function
- Promote National Industries => Porter et al.
- Promote Value of Network => Metcalfe et al

- Focus on regulative issues => Maximize Social Welfare

  - Social welfare may be reduced by
    - Severe lack of spectrum
      - Cost of operation is in ratio to power of cell radius
    - Aggressive taxation
      - Cost of operation is linearly dependent on the demand
    - Aggressive auction prices
      - Cost is not in any ratio to demand
      - The only method to make the business case non-profitable by default



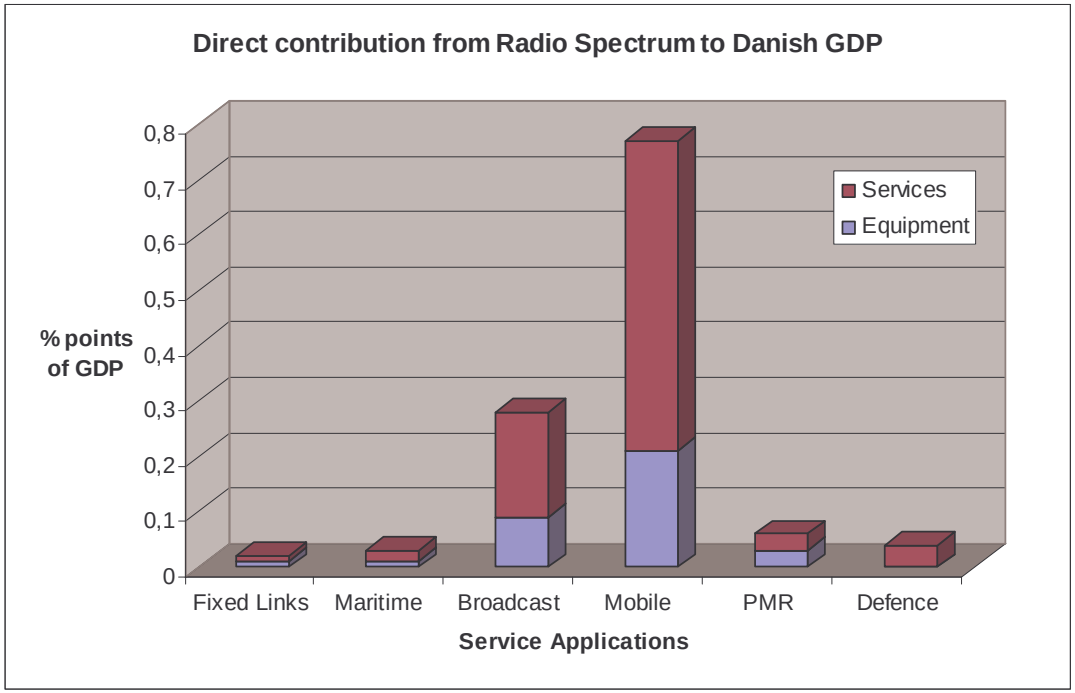
Framework for Social Welfare

- Making and Sharing the cake
  - Consumer surplus: Gain better service than they pay for
    - Consumers of spectrum when using services
    - Consumers of spectrum directly
  - Regulator
    - Representing consumers
    - Representing governments
    - Maximizing social welfare
  - Operators
    - Make profit on services
    - using the Spectrum efficiently
  - Infrastructure and product Vendors
    - Make Profit on Products and service
    - using scale of economies or by differentiation
  - Content providers
    - Making Profit by distributing and selling content via telecom network
  - Governments
    - Safety and security
    - Emergency and Military
    - Gaining Spectrum prices and collecting taxes on services and wages and profits and value add and on and on and on…

- Decision framework
  - Micro-economic
    - Spectrum is raw material and should be allocated (or sold/rented) to the party willing to pay highest bid
  - Macro economic
    - Spectrum enables and facilitates growth of the GDP. Therefore the overall contribution of spectrum to the GDP should be used as a decision criteria.

Contribution to GDP: Case Denmark

- Most important service applications
  - Mobile Communication
  - Broadcast
- Both Services and Equipment impact GDP
  - Services may be more general.
  - Equipment is heavily dependent on the industry in any particular country
- In this study Contribution of the services is the main focus



Traditional Methods to Manage Spectrum

- Regulators apply various methods to allocate spectrum. Free competition for maximizing value of spectrum and public sector needs to guarantee some key services need to be taken into account
  - Administrative decision (in practice in China)
  - Beauty Contest (Finland)
  - Auction (USA)
- Spectrum licensing approaches
  - Allocation: Allocation of Spectrum slots
  - Allotment: Defining the geographical areas for spectrum use
  - Assignment: Assigning spectrum for dedicated application(s) or purpose
- Spectrum license may include special terms
  - Time line for minimum coverage and service mix
  - Maximum time span, Re-selling or returning if un-used period
  - Re-farming costs
  - Deployment conditions (Interference, guard bands)
  - License cost (One time, in advance or Yearly payment (fixed or relative to revenue or profit or number of subscribers)
- It is also possible to allocate spectrum for unlicensed use
  - Anybody can use the spectrum
  - Minimum technical requirements must be fulfilled

When Auction is used, Spectrum has to be paid before network build-up.

Net Present value = Investment. Interest rate is significant factor in business case.

Another way is to collect charges with the growth of the traffic and revenue

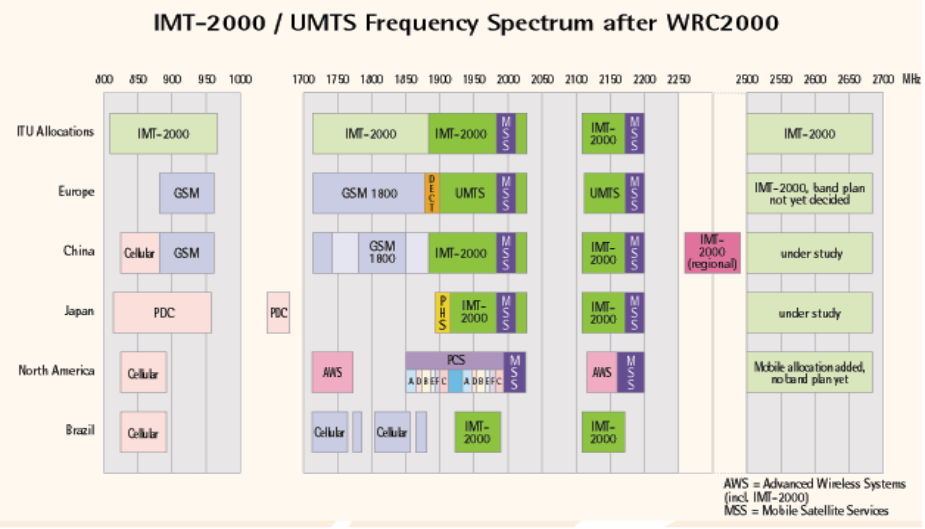
Spectrum management status

- Radio Spectrum has been and will always be regulated somehow
  - Optimize welfare:
    - Maximize utility = Value of services provided to citizens (consumers?) directly or indirectly.
    - Minimize cost of operation = Avoid Technology fragmentation and Spectrum fragmentation, control and set rules for competition of the operators
  - Optimize use of spectrum:
    - Avoid interference between systems
    - Avoid high power transmitters
    - Re-farm radio spectrum is not used efficiently
    - Control/monitor type testing and approval requirements
  - Political reasons: Spectrum for different purposes
    - TV broadcast, Military, Scientific,…and Commercial and Mobile

- Regulation principles driven by legislation. New approaches emerging
  - EU Decision No 676/2002/EC on "a regulatory framework for radio spectrum policy in the EU"
    - Harmonization, Efficient use, avoid Interference,..
    - Spectrum trading, not implemented yet: Spectrum trading may improve non-technical aspects of spectrum efficiency, Flexibility to use radio spectrum, Innovation, Competition, Transparency in management and setting right price for spectrum.
  - FCC
    - FCC (ET Docket 02-135). New ideas of secondary use of spectrum.

Current Spectrum allocations

- Total spectrum allocated for mobile communications by CEPT countries is about 350 MHz and extending to about 590 MHz
  - Most of the spectrum allocated as paired uplink and downlink.
  - Role of TDD spectrum is unclear
  - Extensive re-farming of current deployment is needed in the future.



Source: UMTS Forum

- Spectrum licenses granted on national basis
  - In most of the countries most recent allocations based on spectrum auctions
  - Traditionally spectrum allocated based on beauty contests or by default to monopoly operators

- International coordination in ITU and in regional agencies like in ERO.
  - Minimum requirement is global roaming, general goal is maximum harmonization and avoidance of unnecessary market fragmentation.
  - Also border area coordination is needed, depending on the maximum power level used.

Service Evolution - Maximizing value of Services

- Services define the spectrum needs by
  - setting minimum acceptable technical requirements
  - impacting the number of users using the service.
- Services may be divided into categories based on
  - Quality: Bit error rate and Delay
  - Data Speed: Bandwidth requirements of the transmitted information.
- Service evolution is impacted by enabling technologies
  - Displays, cameras, and other user interface elements
  - Processing power and memory capabilities
  - Various software elements like web browser, email software, music and video players etc.

- Service value may be estimated based on the revenues it creates
- Most valuable services: Mobile Communications and Broadcasting
  - Between 1990 and 2000 overall communications spending has grown from 1% to 3 % in OECD countries
  - Is it reasonable to expect ARPU in Mobile Communications to grow significantly relatively to overall spending ?
    - Video call
    - Information access, streaming video
    - Peer to Peer
  - Is it reasonable to expect ARPU in (Mobile) Broadcasting to grow ?
    - Video streaming

Technology evolution in Mobile Communications

- Main stream technologies include:
  - GSM, GPRS and EDGE
  - WCDMA enhanced with HSDPA and CDMA2000 evolution
  - TD SCDMA in limited areas
  - Other recognized ITU FPLMTS technologies will fade away as well as some of the 2nd generation celular technologies. But the game is open again for the 4th Generation!
- Technology selection and product implementation impacts the spectrum efficiency drastically.
  - WCDMA and CDMA200 are the main selected air interface technologies for 3rd generation. We can use these systems as reference.
  - Any 2nd generation systems and their evolution options will reach some 60-100 % of the 3rd generation figures in Spectrum efficiency
  - Performance is heavily dependent on implementation aspects:
    - Dynamic range of receivers and transmitters
    - Use of hierarchical and sectorized cells
    - Use of advanced algorithms such as MUD and MIMO.
  - WCDMA will have capacity extension using HSDPA which will impact specifically downlink packet traffic performance.
  - High mobility and outdoors to indoor coverage requirement impact spectrum efficiency.

=> Let's assume the basic WCDMA spectrum efficiency being according to some early simulations: 200 kbit/MHz/cell. This will improve by factor of 2-4 in the long term future

(the figures are quite different for uplink and downlink and for different traffic channels. Performance various significantly also under various other constraints but for this study simplified model may be used)

Estimating the Spectrum needs

- We can estimate:
  - Number of Users: N, Bandwidth requirements: B kbit/s
  - Spectrum: S MHz, Spectrum efficiency: ρ kbit/s/MHz/Cell; 200 kbit/s/MHz/Cell for first phase WDCMA
  - Cell radius: r m
  - Capacity or the cellular network: $N*B = (S* \rho * 1/r^2)$
  - Minimum cell radius defined by technology parameters, between 50..200 m in practice
  - Capacity is reduced to zero for infinitely large r

- Examples:
  - Spectrum need is a function of service mix, number of simultaneous users and density of the users and their mobility behavior. To balance the worst case assumptions, we may assume that all the data is either created and consumed real time. Background traffic has no delay constraints because of continuous coverage.
  - In order to estimate the maximum needs some worst case value may be defined. Let's assume:
    - Case 1: London metropolitan area: 10 million people, Penetration 100%, area 3000 km^2.
    - Case 2: London Heathrow Airport 2 meter average distance between people
    - Service mix: 200 mErl voice traffic (10 kbit/s, duplex), 100 mErl Mobile Video conference (144 kbit/s duplex), 10% of the people browsing with multimedia content (256 kbit/s simplex)
    - ⇒ Total load in downlink is

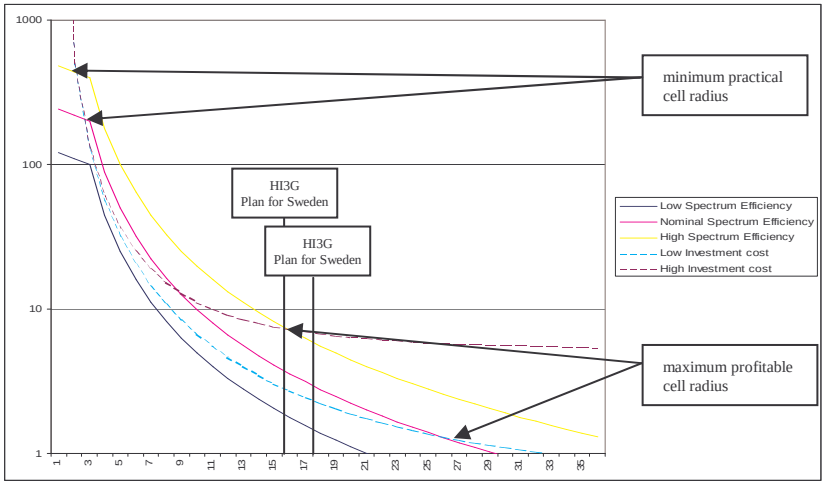
    Case 1: 10M/3000*(0.2*10+0.1*144+0.1*256) = 140 Mbit/s/ km^2.
    Case 2: 500*500*(0.2*10+0.1*144+0.1*256) = 10.5 Gbit/s/km^2.

  Note: It may not be rational to assume the same service mix for both cases. Both of these cases are much higher than assumed in most market studies.

  - Nominal cell size for London Metropolitan area using UMTS at 2x10 MHz spectrum allocation => r = SQRT ((1M*S* ρ)/(pi*N*B) = 67 m => Almost practical even for one operator. When 60 MHz band is available (all operators) => r = 165 m
  - Nominal cell size for LHR using UMTS at 2x10 MHz spectrum allocation => r= 7.8 m => Impractical. Using all current mobile downlink FDD spectrum (150 MHz) r = 30 m. Even this is impractical. One must assume advances in technologies, which will enhance spectrum efficiency by factor of 4 or more => r = 60 m…Getting there in indoor environment, fi service mix is ok ? How about high use of entertainment in mobile ? => DVB

Estimating Spectrum needs

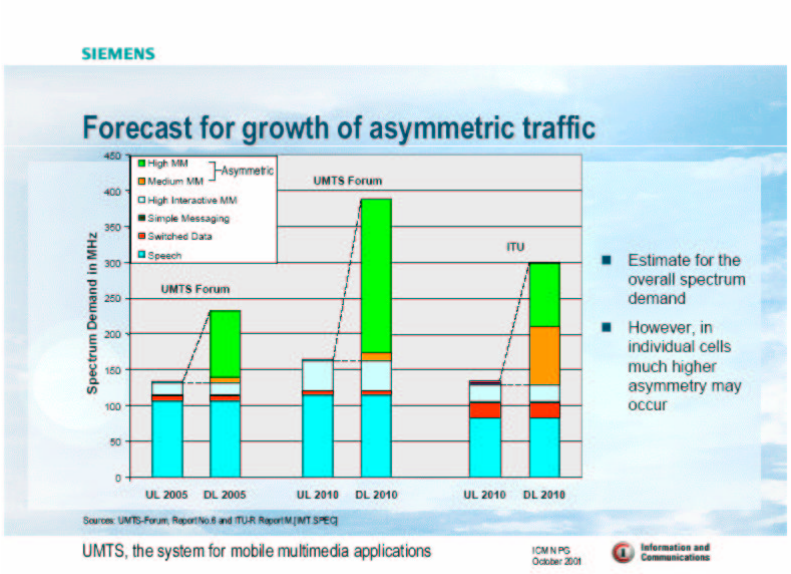
- Cellular system is profitable when there are users enough to cover the investment and operating costs
- High initial Investment costs require high capacity network to be built as default
- Low Spectrum efficiency can never support high initial investment cost networks ever
- High initial investment cost makes rural coverage non-profitable by default.
- This can not be addressed by single technology/spectrum slot. Dual mode and dual band radio system needed.

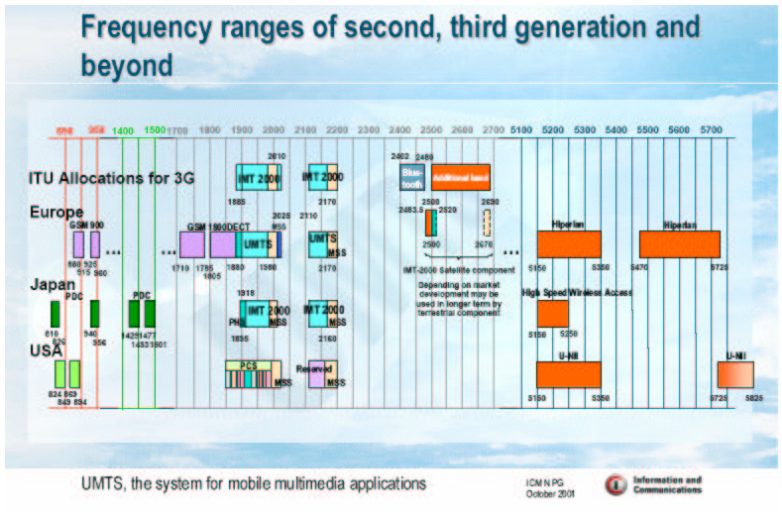


Qualitative drawing about impact of initial investment requirements to usable cell radius

Extension bands and new technologies

- Asymmetry
  - Asymmetry of the Current WEB traffic
  - Asymmetry of the radio technologies
  - Symmetry of P2P Traffic
- Spectrum fragmentation
  - Use of Guard-bands
  - Availability of wide band width filters and other components
  - Variable Duplex or TDD
- Near Far effect
  - stumbling block for UWB ? (There is no ”below noise level” approach)
- Value of Spectrum as a function of frequency
  - Propagation is relative to $1/r^2$
  - High frequency improves re-use





Regulative pitfalls in the past

- Spectrum allocated but not used
  - Tragedy of Anti Commons; MMDS (and ITFS)
  - Wrong technology assessment; DAB ?
  - Wrong commercial assessment; Bankruptcy of the operator
- High Auction price slow down the industry in general and reduce the GDP
  - Germany and UK
- Fragmentation of the spectrum due to incompatible technologies
  - USA PCS
- Public Regulation process slows down innovation and keep the cost of equipment and networks high
  - Fixed allocations per applications. Assignment of spectrum for certain technology prohibits technology innovation and enhancements. Interference complaints used to block competition. US PCS
  - More liberal approach will raise demands to re-use current spectrum without new allocation process, which leads to unfair competition: Nextel
  - Extremely slow execution of re-allocation process:

Flexible regulative regime

- Re selling of the licenses under current license conditions
  - Gradual transition of old technologies/services to less valuable bands or to cable
  - Using current spectrum licenses more effectively: Tax is better than auction!
- Innovative mechanisms and technologies
  - Transition to all digital technologies in all services, including broadcast, satellite and military
  - Local use of licensed spectrum for unlicensed or auxiliary licensed use (Case: UWB)
    - Either the current license owner or regulator or both define the conditions, including insurance type guarantees to manage the interference
  - Real time charging of spectrum use
    - End user pays spectrum directly to the government, Billing and charging done by the operator.
  - Develop new regimes for private systems
    - Mesh (adHoc) networks. How the end users can re-sell their air time and product capabilities
- Maintain (or Increase) competence level of the regulators
  - New technologies extremely complex to assess and manage
    - Not all new proposals really work
  - Political and Commercial pressure will grow higher

Summary

- Radio spectrum is valuable asset.
  - There seems to be spectrum enough in principle
- Should be used to support mobility
  - Fixed use of radio should be limited as far as possible
- Technology innovations shall be taken in use
  - Radio, Network, Network planning, Applications
- Balanced use of broadcasting and cellular technologies
  - Use Broadcast technologies for Broadcast transmission
- Multimode and Multiband radios needed
  - Solve coverage and capacity with different technologies and on different bands
  - Licensed spectrum for high range at low frequencies
  - Unlicensed spectrum for high capacity at high frequencies
- Global core bands must be preserved for roaming
  - National deviations can be tolerated but each deviation will reduce social welfare
  - Avoid fragmentation of licensed spectrum
- Faster and more effective regulation is needed
  - Faster decisions
  - New technologies to support real time sharing, allocation and assignment