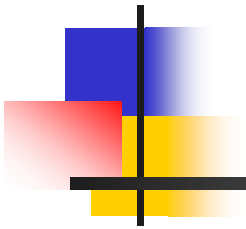
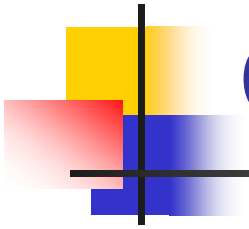


Wireless Network Models

Chapter 3

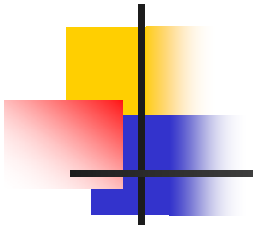


Outline

- Wireless Networks
- Performance measures
- The RRM problem
- QoS in multiservice systems
- Conclusions

Wireless Networks

what are the technical issues ?

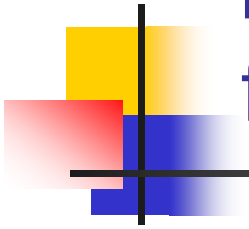


- Wireless system
  - Infrastructure
    - Base stations (RAPs)
    - Fixed network
  - Terminals
- Coverage requirements
- Service requirements

Performance criteria

- Capacity
  - Number of subscribers served
  - Bitrate/Bandwidth provided
- Quality
  - BER
  - Delay
- Service probability
  - Coverage
  - Outage probability
  - Blocking/Service denial

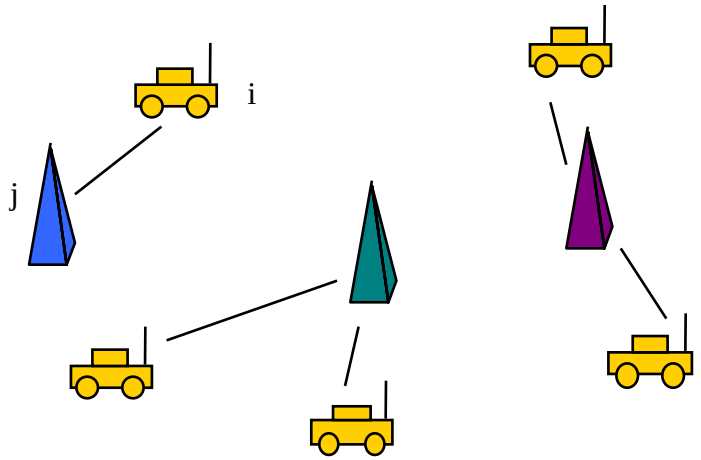
Resource Management problem formulations



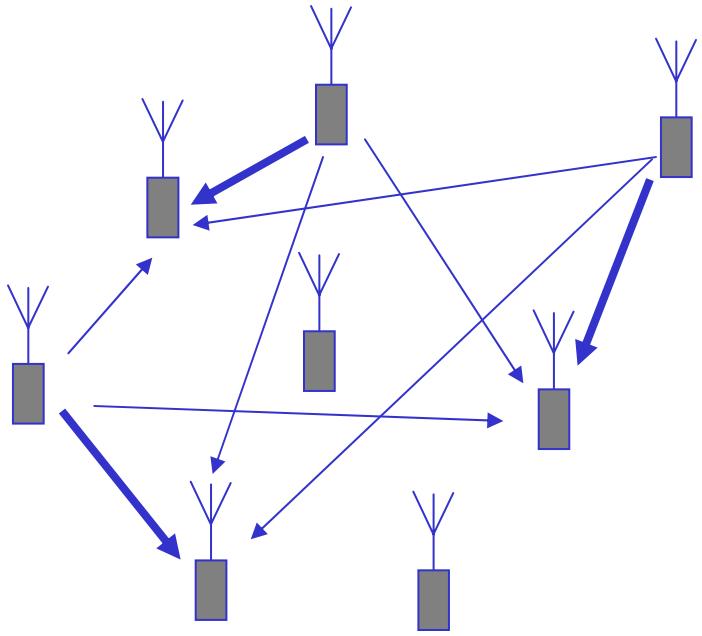
- Commercial Operator:
  - Maximize profit (Revenue – Cost)
  - User performance as constraint
- Alternative (?)
  - Maximize user performance
  - Constraint: No of users, Cost

Radio Resource Allocation problem

- For given infrastructure:
- To each active terminal assign
  - Base station
  - Waveform (“Channel”)
  - Transmitter power
- Such that Link Quality & power constraints are satisfied for as many terminals as possible

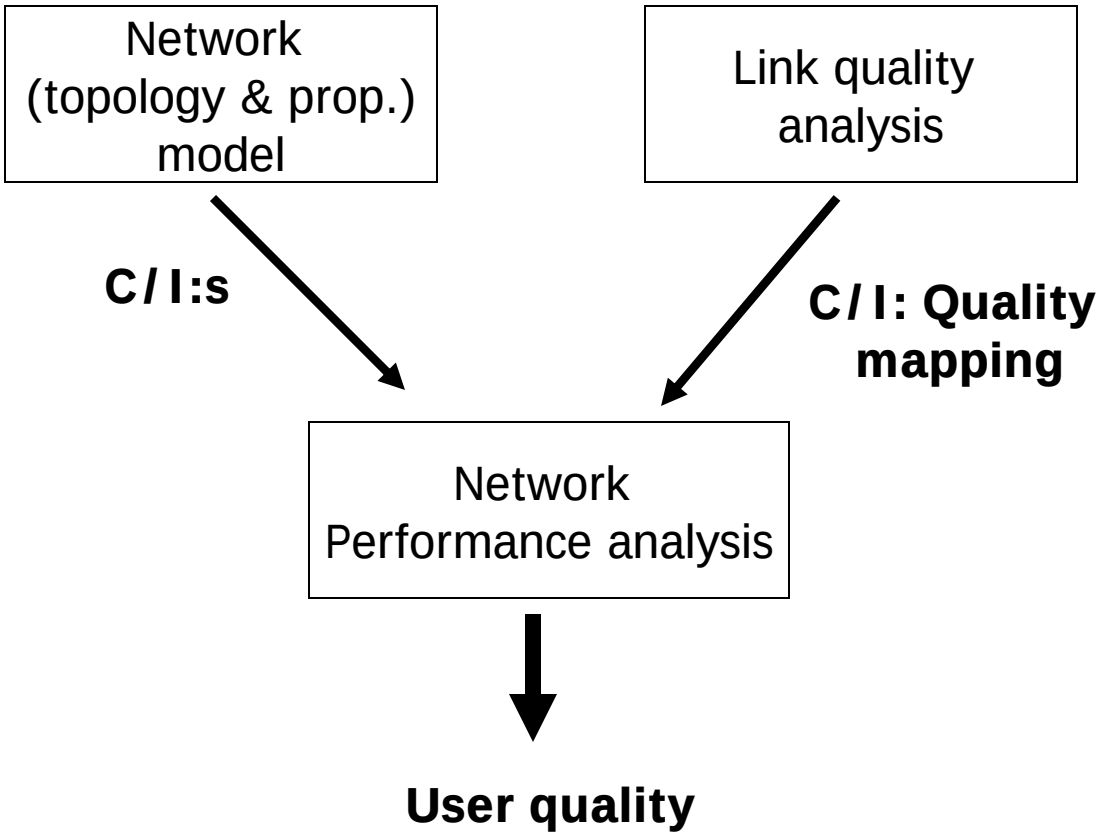


Wireless Networks Analysis



- Multiple transmitters – Multiple receivers
- Complex propagation pattern
- Two step Analysis:
  - What is the current interference situation ?
  - What is the received quality for a given interference situation?

Network Analysis strategy



- Compute C/I in individual links
- Map C/I -> Quality

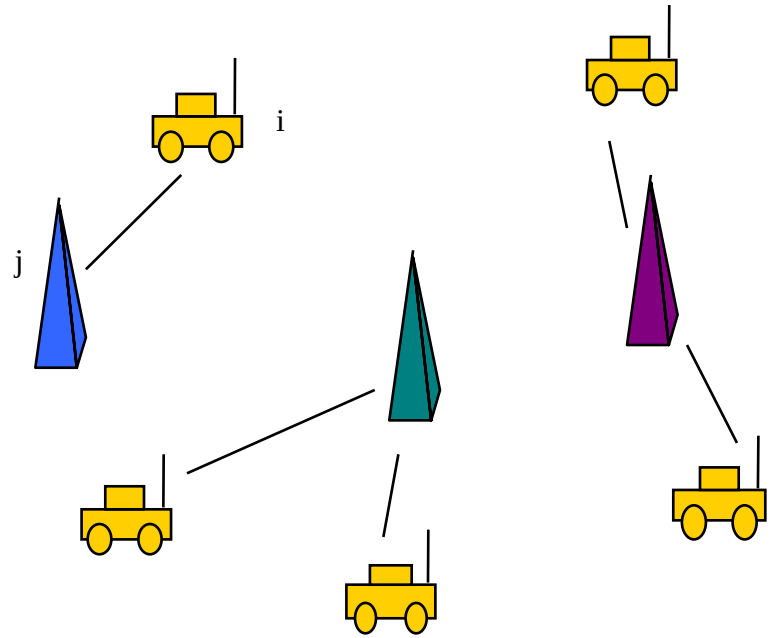
Interference models

- Arbitrary collection of wireless links
- Propagation conditions on link (i,j) characterized by G_{ij} ; the instantaneous link gain

$$P_{rx,j} = P_{tx,i} G_{ij}$$

- Link gain matrix (NxN)

$$G = \{G_{ij}\}$$



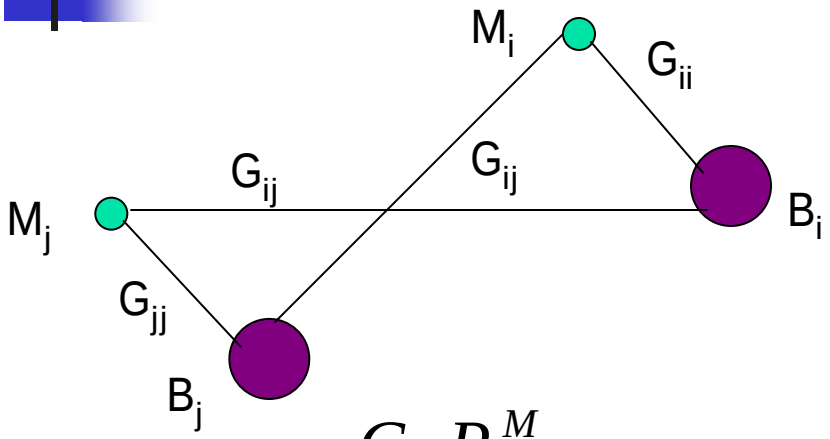
Interference & Quality model

- Performance measure:
  - Effective Signal-to-Interference (+Noise) Ratio SIR ("C/I")
- θ_{ij} Normalized cross-correlation
- Outage probability :

$$P_{out} = Pr[\Gamma_i < \gamma_o]$$

$$\Gamma_i = \frac{G_{ij} P_j}{\sum_{k \neq j} G_{ki} P_k \theta_{ki} + N_i}$$

Special case:
Cellular system - Orthogonal signals

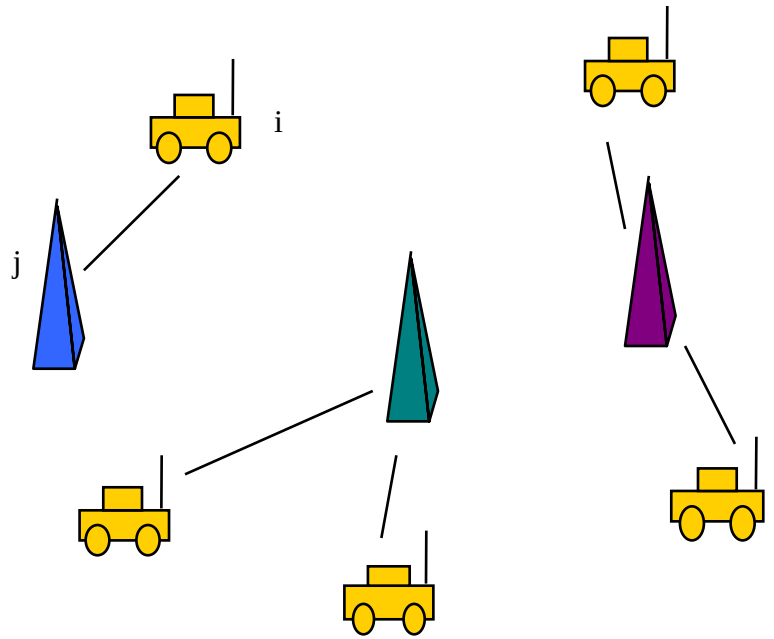


$$\Gamma_i^U = \frac{G_{ii} P^M}{\sum_{j \neq i} G_{ji} P_j^M + N_i}$$

$$\Gamma_i^D = \frac{G_{ii} P^B}{\sum_{i \neq j} G_{ji} P_j^B + N_i}$$

- "Channel"-by "Channel analysis
- At most one mobile & base station per cell active
- Simplify indices – number mobiles & base stations by cell number
- Separate Up/Down-link calculation

Propagation modeling

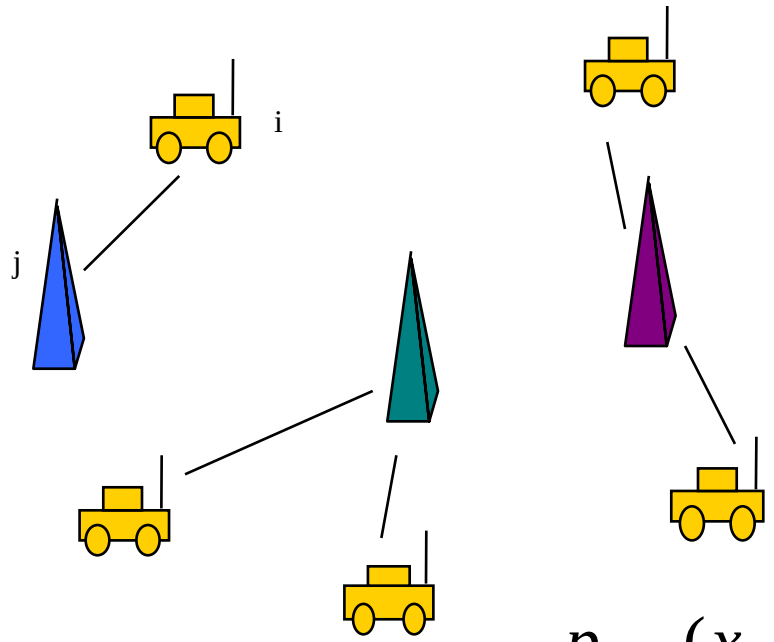


- Gain Matrix

$$G = \begin{pmatrix} G_{11} G_{12} \cdots G_{1M} \\ G_{21} G_{22} \cdots G_{2M} \\ \vdots \quad \vdots \quad \cdots \vdots \\ G_{B1} G_{B2} \cdots G_{BM} \end{pmatrix}$$

- B Base stations/access ports
- M Mobile terminals

Traffic modeling

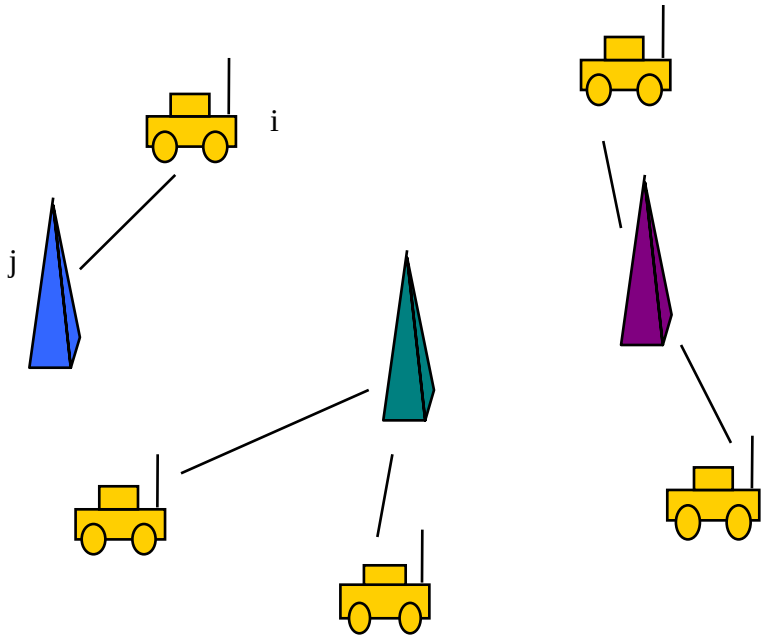


- M terminals uniformly distributed
- ω terminals per area unit
- given one terminal at (x,y) in area A

$$p_{X,Y}(x,y) = \Pr\{[X \in x+dx],[Y \in y+dy]\}$$

$$= \frac{1}{A} dxdy$$

Capacity definition



- Gain Matrix
- M terminals active
- Y terminals served
- Z=M-Y assignment failures
- Assignment failure rate

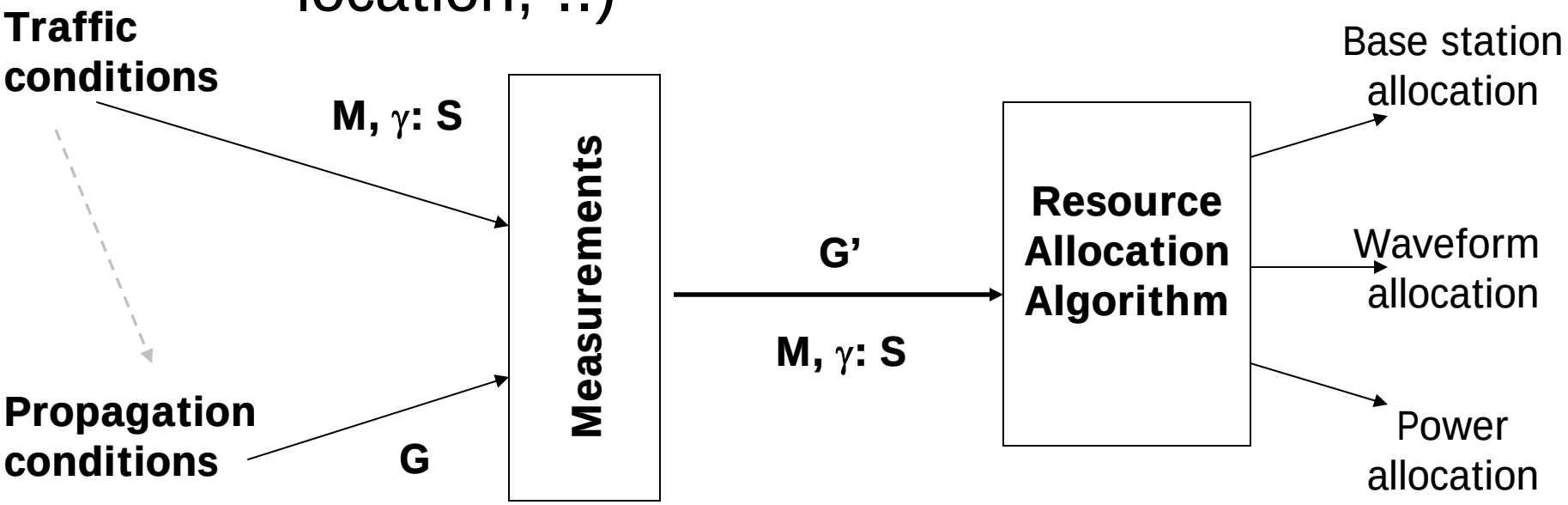
$$\upsilon = \frac{E[Z]}{E[M]} = \frac{E[Z]}{\omega A}$$

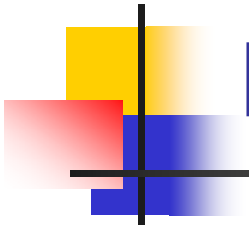
- Capacity

$$\max \omega : \upsilon = \frac{E[Z]}{\omega A} \leq \upsilon_o$$

Resource Management Strategies

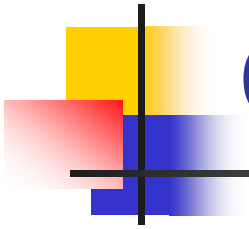
- Input data
  - User requirements (Traffic conditions)
  - Environmental conditions (Propagation, location, ..)





Resource Management Strategies

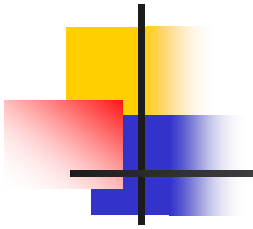
- Preplanning strategies
  - Fixed channel allocation based on statistical information (average traffic, propagation prediction)
- Real-time measurement
  - Decisions based on actual measurements



Channel (Waveform) Assignment

- Static assignment
- Dynamic Channel assignment
  - Traffic adaptive assignment
  - Signal Strength adaptation (Reuse Partitioning)
  - Interference adaptive assignment
- Random assignment
  - SFH
  - DS-CDMA

Static channel assignment ("Cell planning")

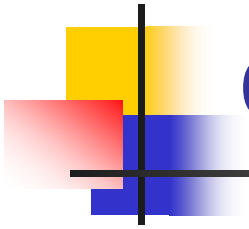


- Input data
  - Propagation predictions
    - GIS / Statistical
  - Average/Peak traffic predictions
- Use orthogonal channels/time slots
- Create "cell plan" assigning channels to base stations

Wireless Internet - the main 3G driver ?

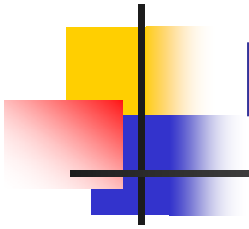
- What is “Internet” ?
  - To “the man in the street”= Web-browsing – multimedia service platform
- “Multimedia”
  - Interactive information services
  - Streaming audio/video
  - etc

New Service requirements - consequences:



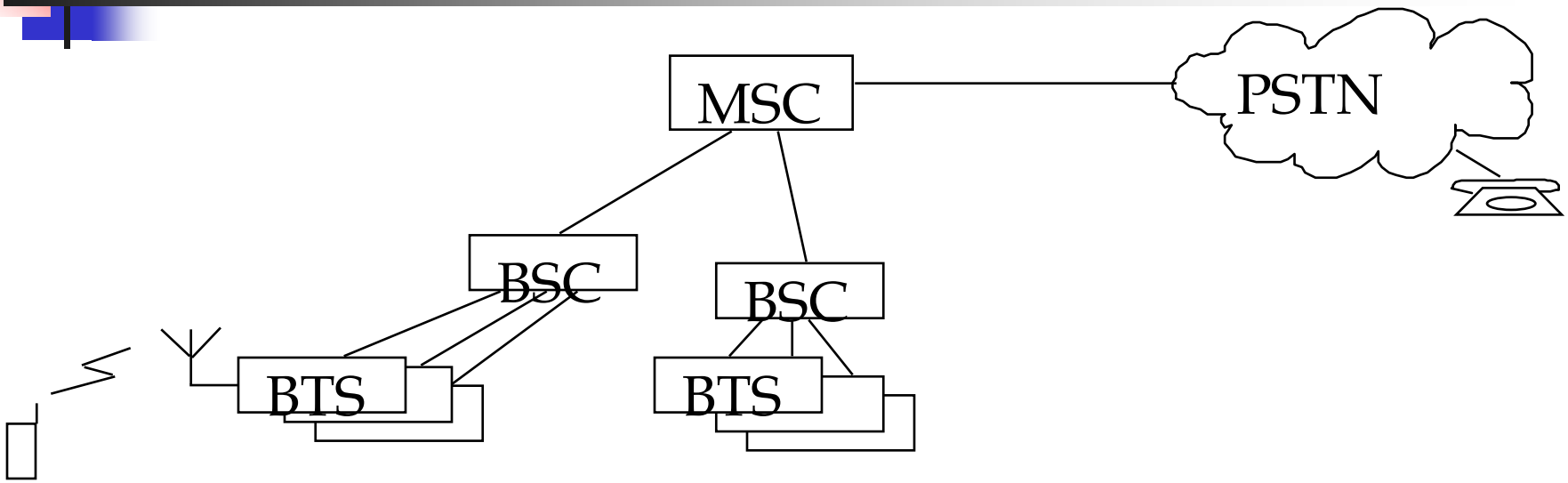
- High bandwidth
- Multiple QoS requirements
- Packet oriented systems – always connected
- Asymmetric traffic patterns
- Unlicensed operation

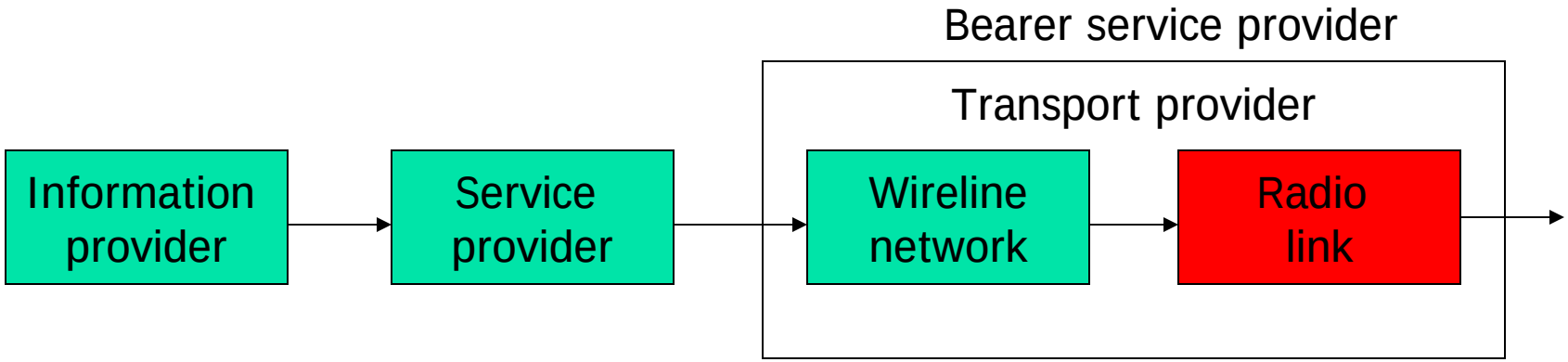
Multiple-QoS Radio Resource Management - characteristics

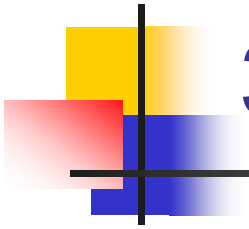


- “Multimedia traffic” = different QoS requirements: i.e.
  - Error performance
  - Delay
  - Date rate (throughput)
- Non-real time traffic vs. **RT/Voice-traffic**
  - Guarantee minimum throughput (average data rate)
  - Utilize all available throughput at any time (best effort
  - Guaranteed constant data rate & delay

Service provision in modern information-communication system







3G & QoS Profiles

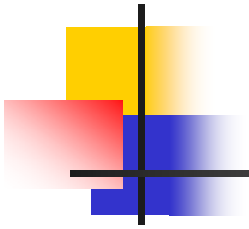
- Maximum data rate
- Guaranteed data rate
- Maximum *packet/message* size
- Residual bit error rate: undetected error rate after delivery over the service interface
- Transfer delay
- Priority

3G Service classes

Service Class	*Typical applications*	*Service Function Characteristics*
Conversational Real time (RT)	Voice	• Preserve time relations between entities • Stringent preservation of conversational patterns (low delay)
Streaming RT	Video/Audio streams	▪ Preserve time relations between entities
Interactive Best effort (BE)	Web-browsing	• Request-response pattern • Preserve payload (low error rate)
Background BE	File transfer, e-mail	• Not time critical • Preserve payload (low error rate)

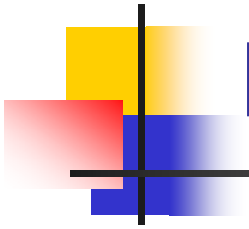
3G Service class parameters

Traffic class	Conversational	Streaming	Interactive	Background
Max bit rate	< 2000	< 2000	< 2000- overhead	< 2000- overhead
Max PDU (bytes)	< 1500	< 1500	< 1500	< 1500
Guaranteed bit rate	< 2000	< 2000		
Transfer delay (ms)	80- max value			
Priority	1,2,3	1,2,3	1,2,3	1,2,3
Residual BER	$5 * 10^{-2}$,10^{-2}, 10^{-3},..., 10^{-6}	$5*10^{-2}$,10^{-2}, 10^{-3},10^{-4},10^{-5}...,10^{-6}	$4*10^{-3}$,10^{-5},10^{-8}	$4*10^{-3}$,10^{-5},10^{-8}



Multiple QoS Radio Resource Management – challenges

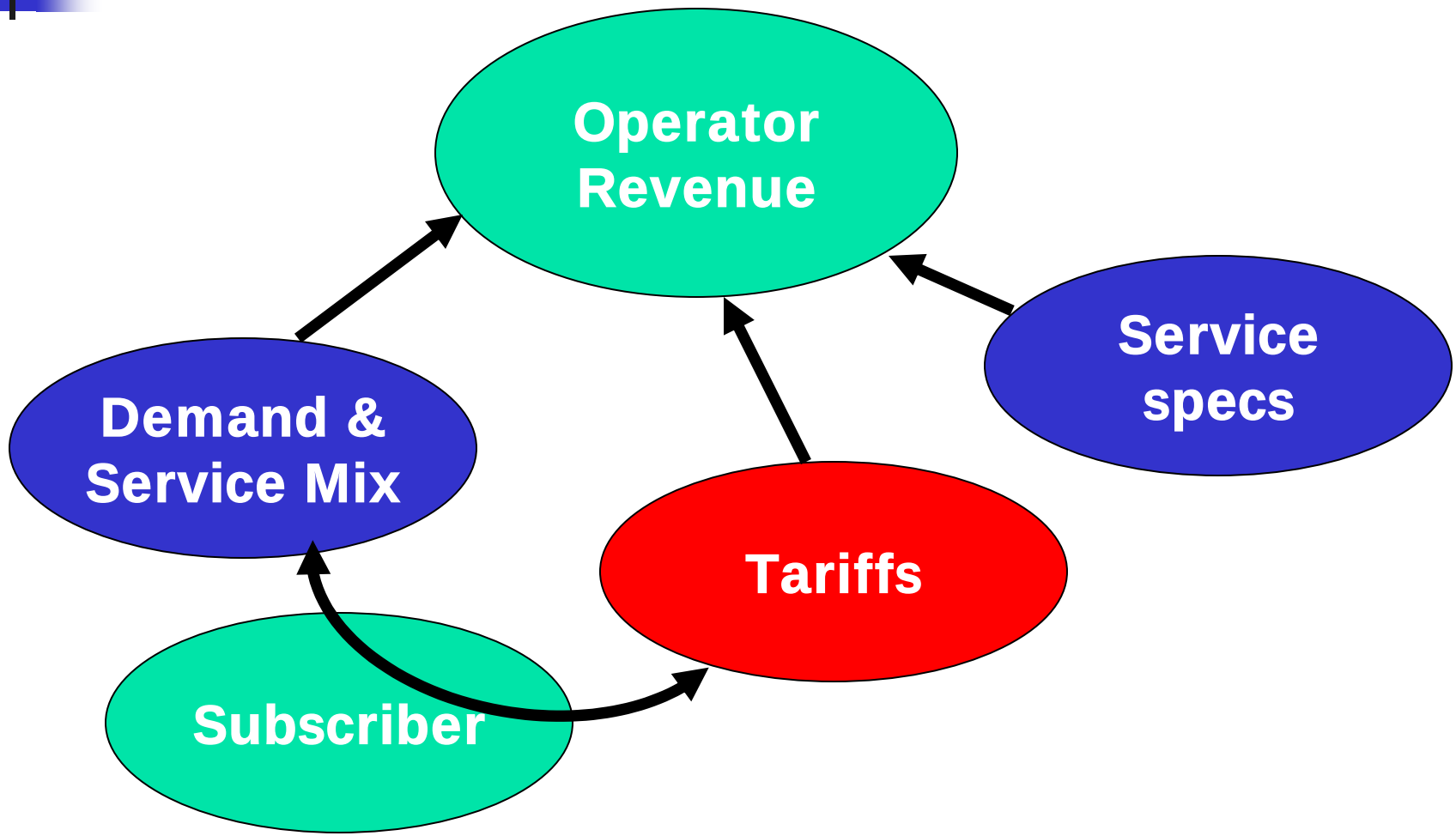
- Objective function hard to formulate
  - Multi-dimensional performance measures
- No direct correspondence between resource consumption and perceived performance:
  - Speech user in poor location may consume more than High speed data user within LOS

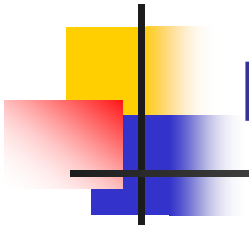


New Performance Measures

- *Service denial probability*:
  - Prob. of denying a user to *begin* a certain session due to resource shortage
- *Service interruption probability:*
  - Prob. of forcing a user to *terminate* a certain session due to resource shortage

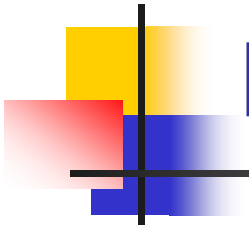
Formulate in Economical Terms ?





Novel Resource management techniques

- Waveform selection
  - Rate adaptation
  - Interference avoidance
- Packet oriented techniques & scheduling
- Dynamic vs Random Channel Allocation
- Multi-QoS RRM
  - Scheduling & Queuing strategies
  - QoS Contracts & Guarantees
- Adaptive Antennas
- Integrated Resource Management



Resource management problem

- Resources to be managed/conserved
  - Radio frequency spectrum
  - Power consumption
  - Infrastructure cost
  - Terminal cost