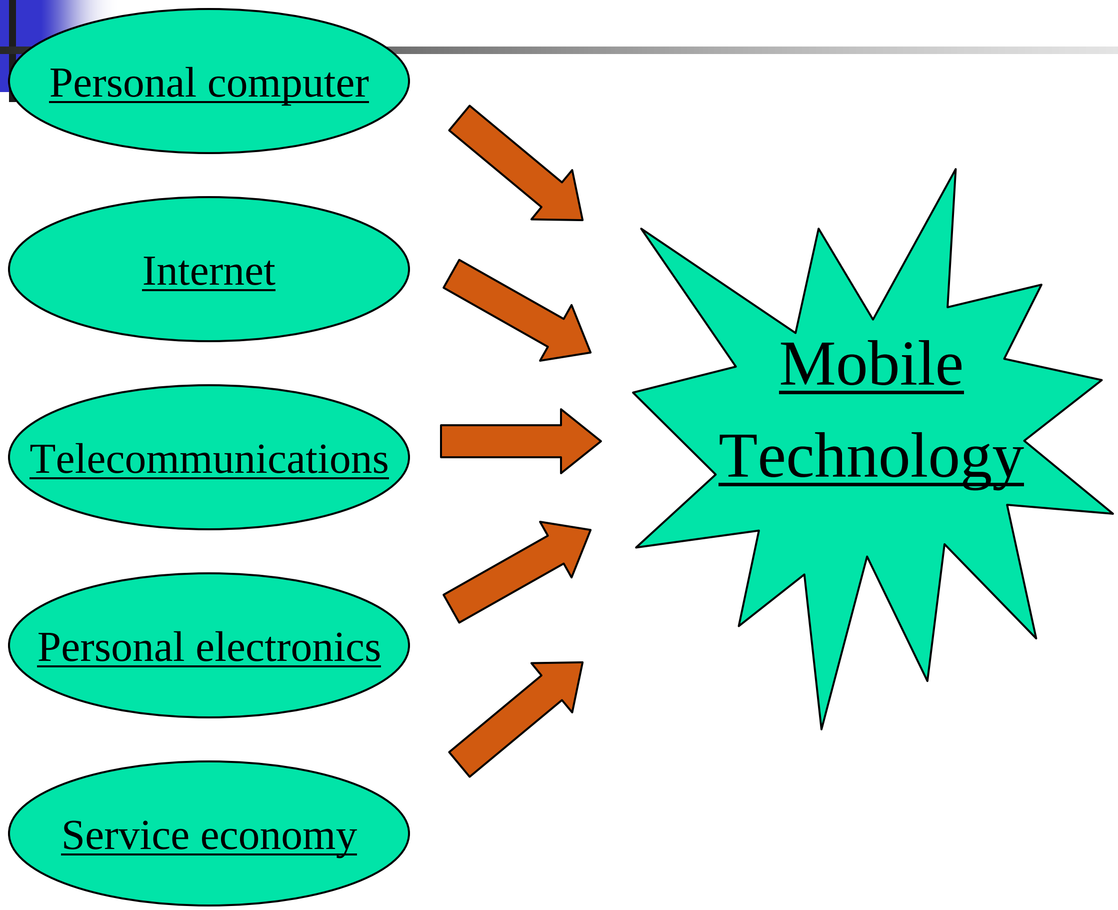
Multimedia Document Communications over Wireless Network

Convergence of Mobile Services



Access to any data

Ubiquitous

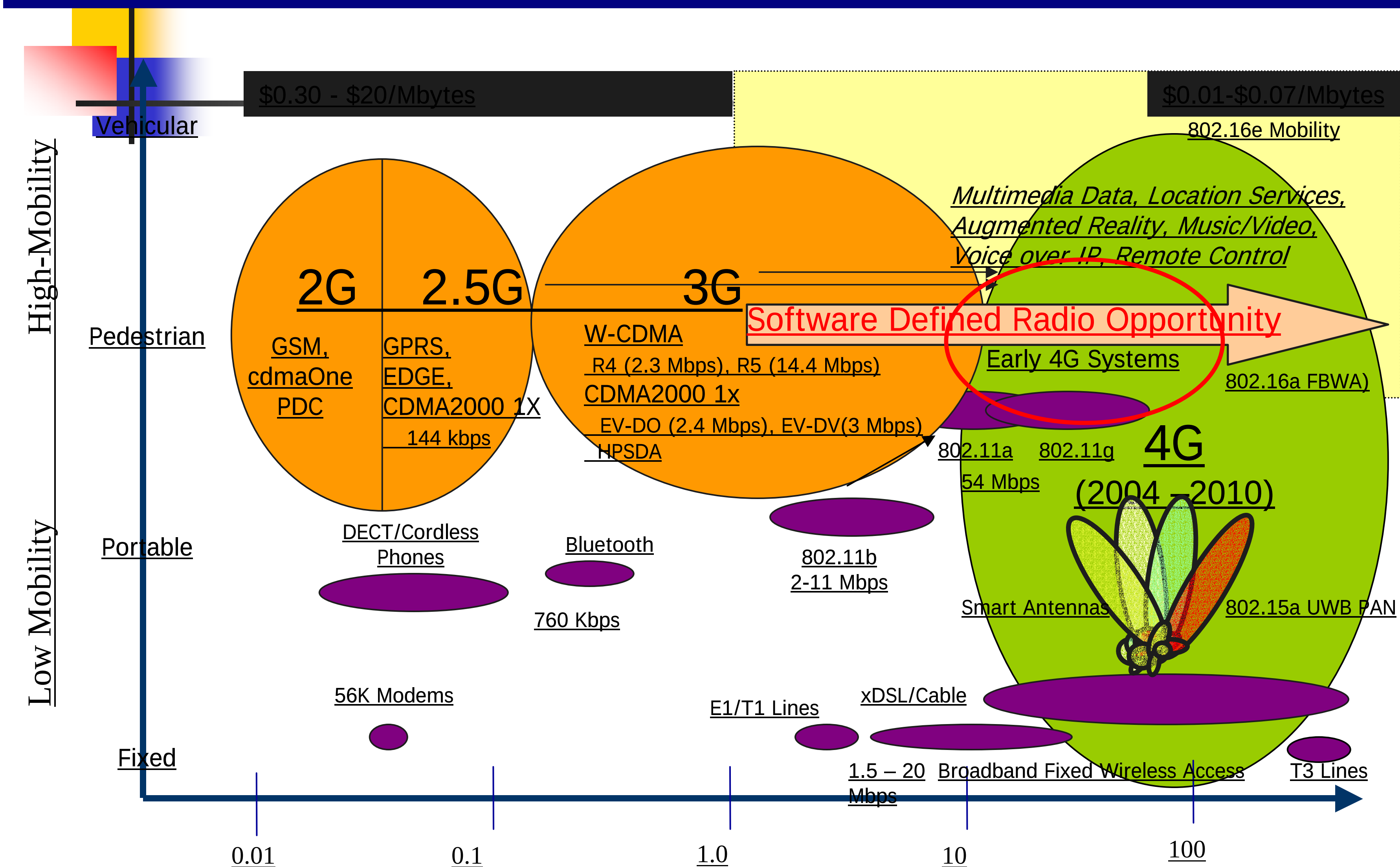
Portable processing power

Intuitive, augmented reality interfaces

Context / location aware

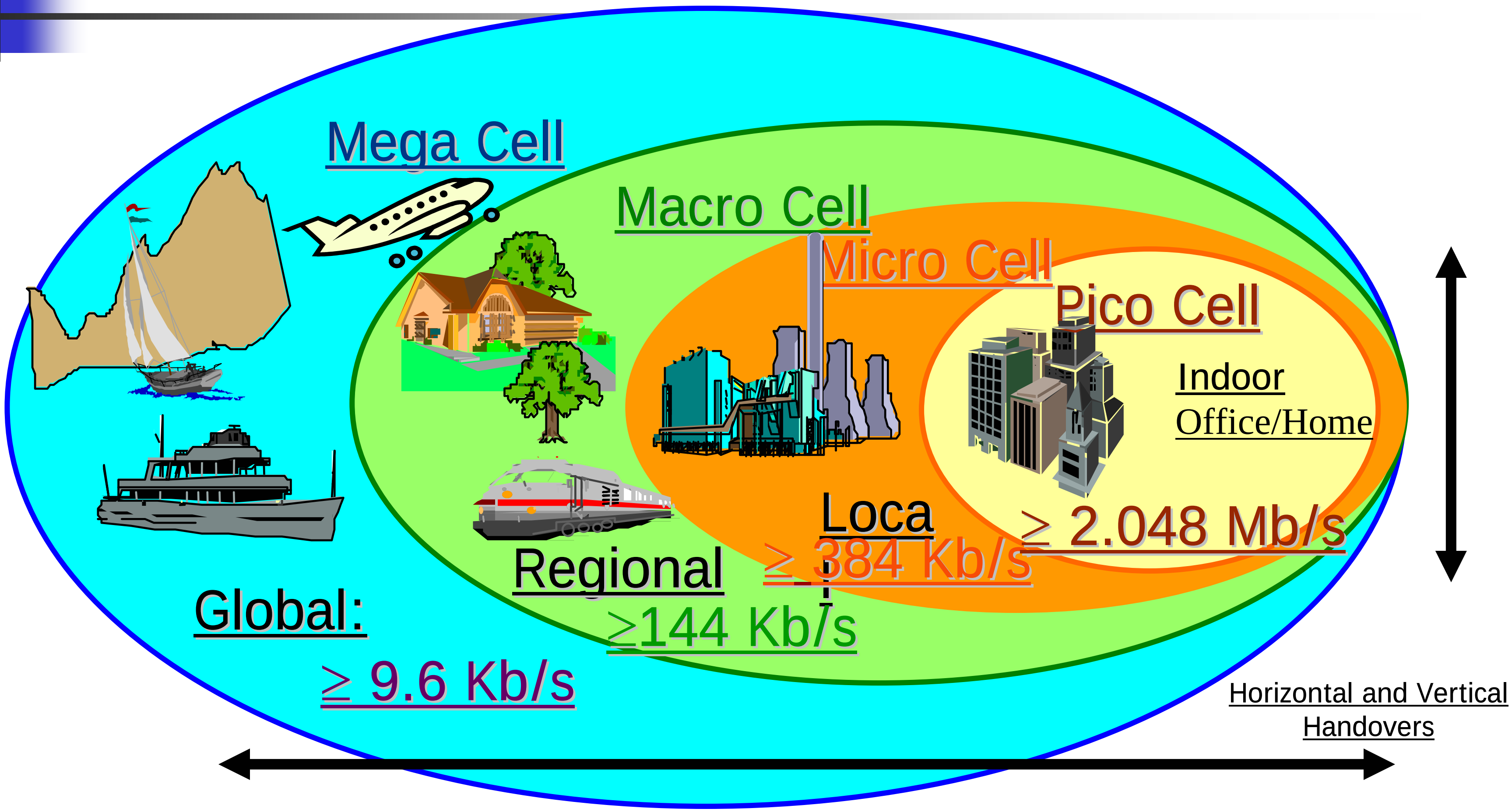
Simplifying and enriching people's lives

4G Wireless: >40-150 Mbps Transmitters



Source: Alex Lightman & William Rojas *Brave New Unwired World, John* Wiley & Sons: 2002

ITU's IMT-2000 Requirement for Minimum Data Rates



IMT-2000: ITU's 3G initiative: Task Group 8/1 (International Mobile Telecommunications-2000)

4G Concept

How to support user/application-specific quality of presentation (QoP)-based delivery of multimedia data/documents within and across layers in a context-aware environment

Reasons to Have 4G

- Support interactive multimedia services: teleconferencing, wireless Internet, etc.
- Wider bandwidths, higher bit rates.
- Global mobility and service portability.
- Low cost.
- Scalability of mobile networks.

Comparison of 3G and 4G

3G

•Back compatible to 2G.

•Circuit and packet switched networks.

•Combination of existing & evolved equipment.

•Data rate (up to 2Mbps).

4G

•Extend 3G capacity by one order of magnitude.

•Entirely packet switched networks.

•All network elements are digital.

•Higher bandwidth (up to 100Mbps).

Context-Aware Environment

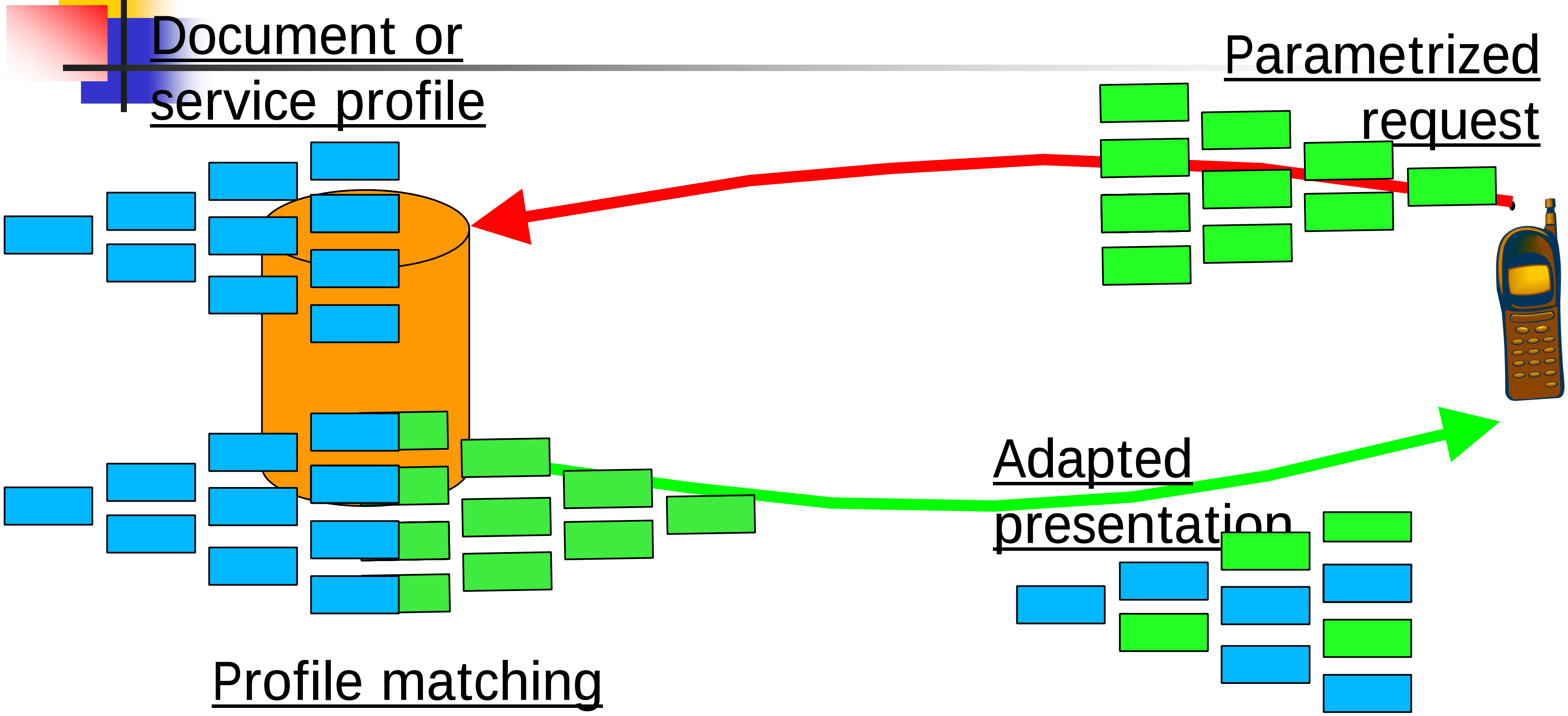
What is context?

Context-dependent information has two aspects:
Environmental adaptation, and personalization.

Growing need for 4G multimedia applications!

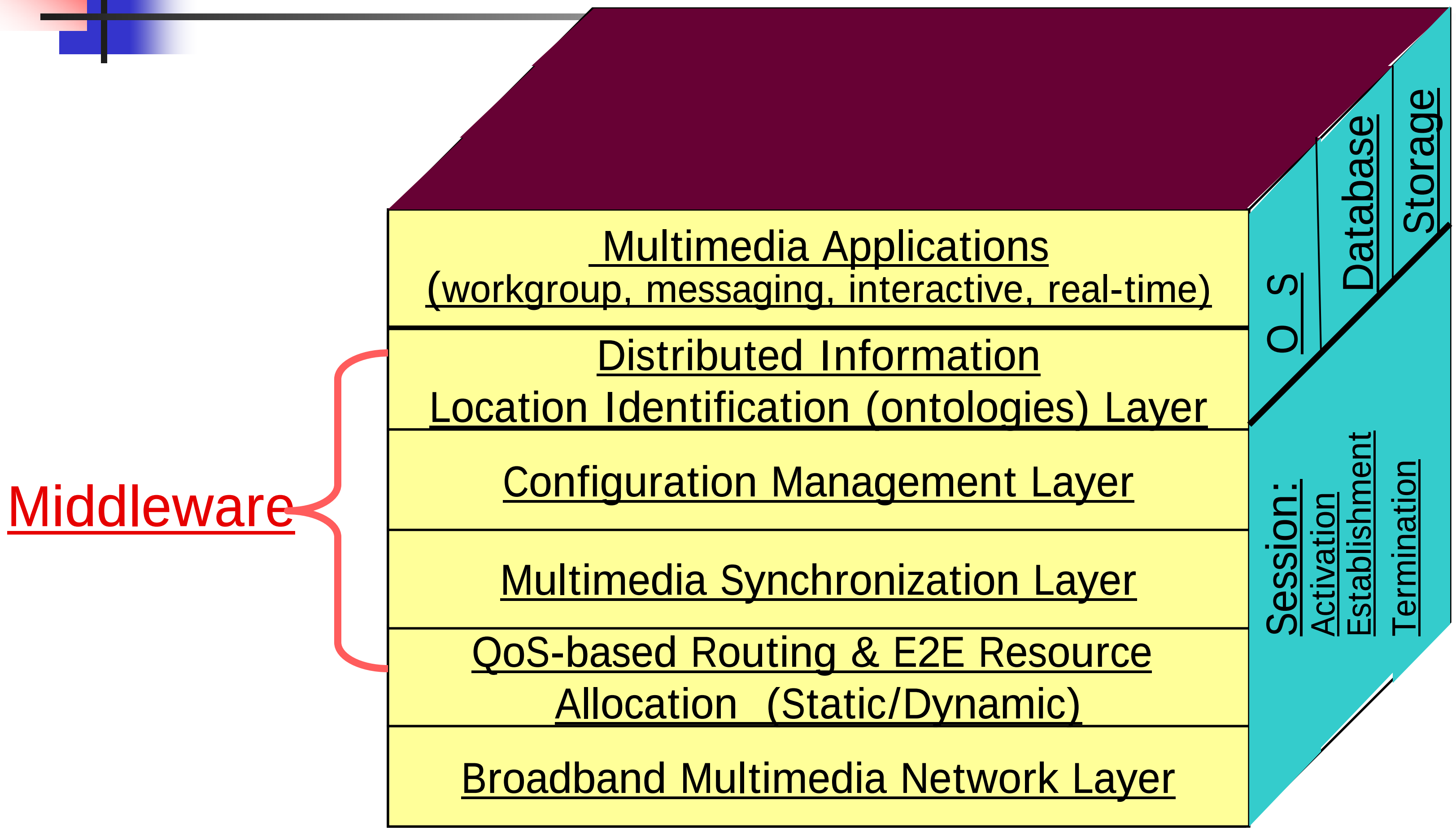
- End-device
- Preferences for the use of the device
- Environment
  - Location
  - Weather
  - Time
  - Agenda

Context-Aware Environment

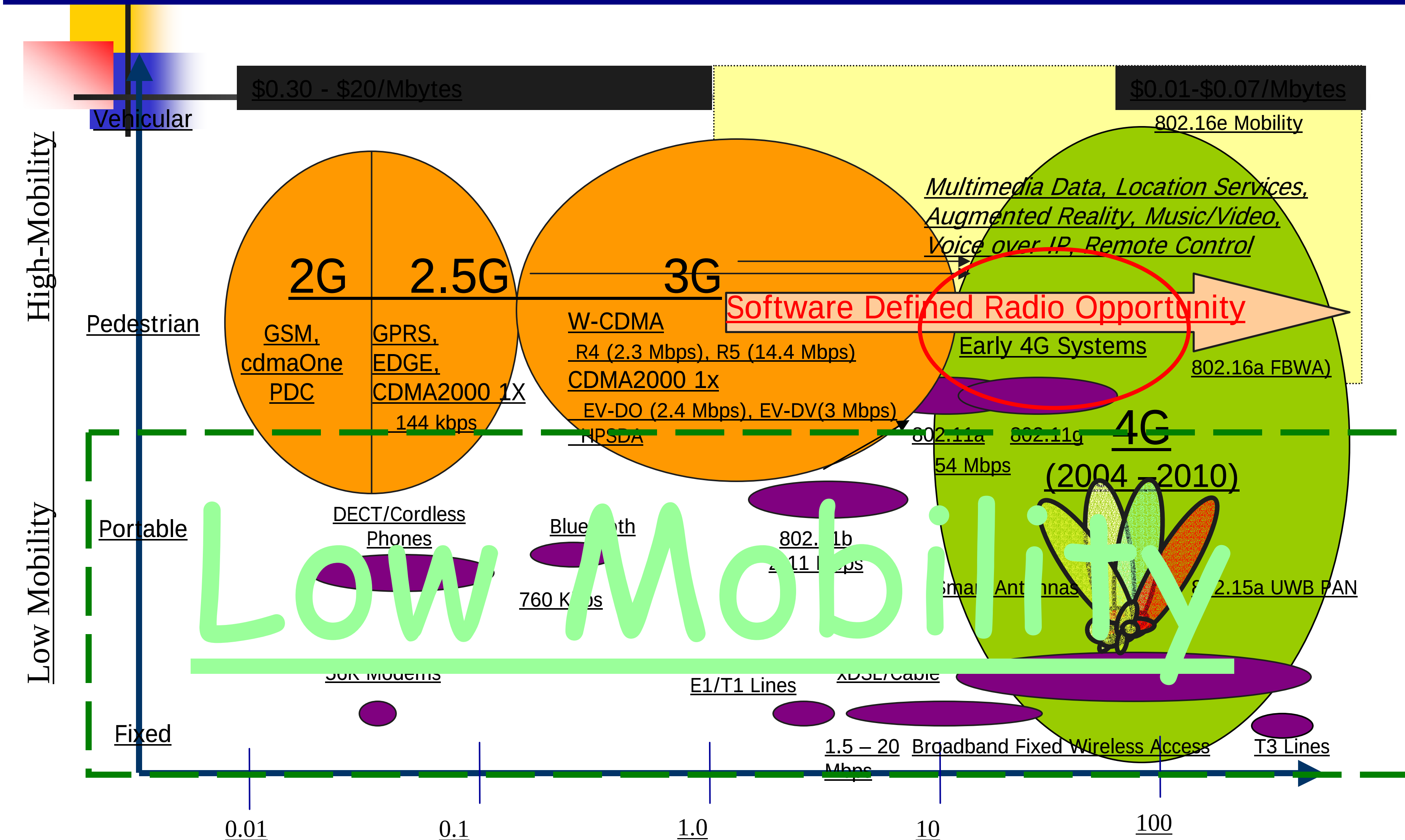


The technology is an enabler for future Web-based multimedia systems

Networked Multimedia System Architecture



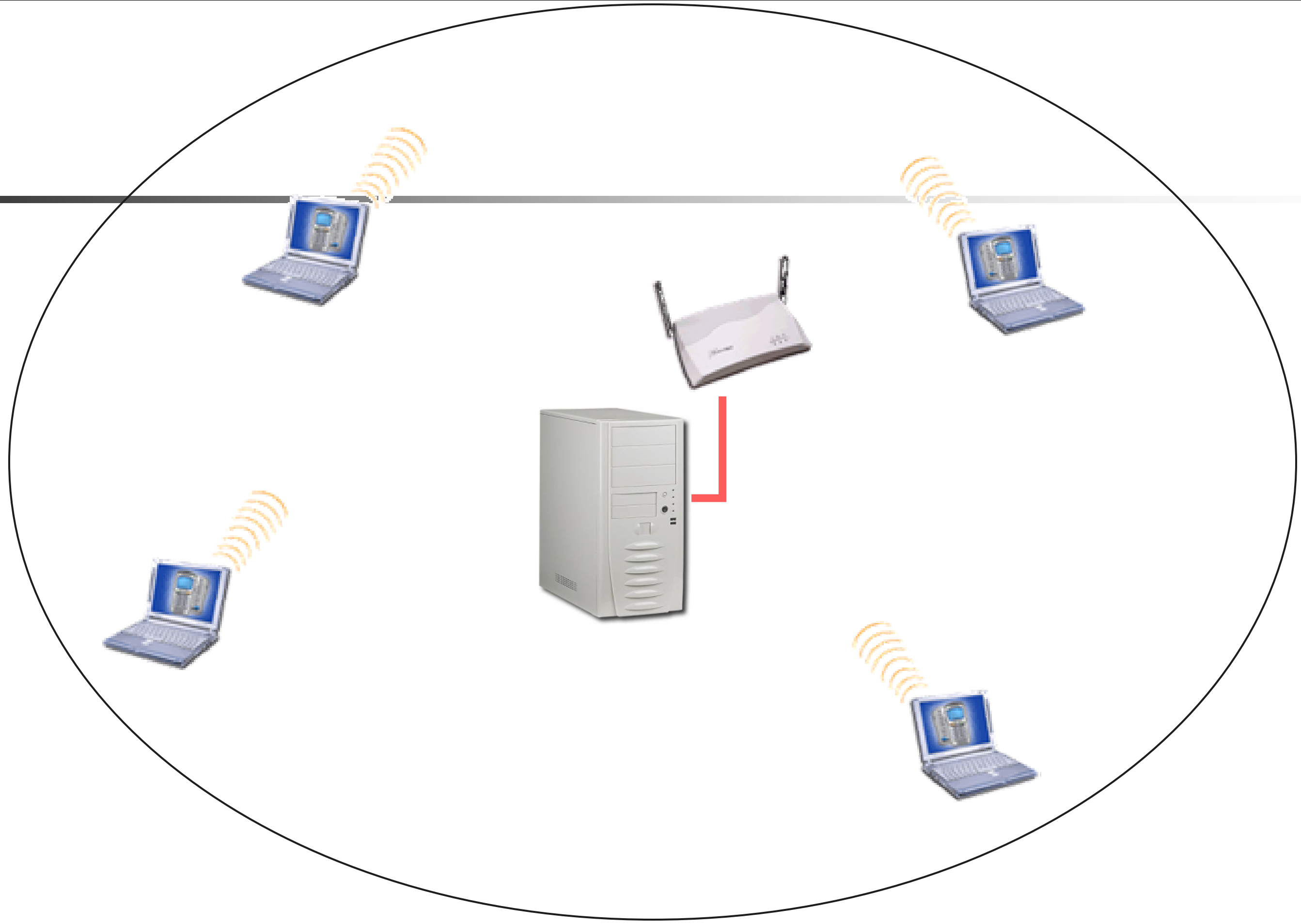
4G Wireless: >40-150 Mbps Transmitters



Source: Alex Lightman & William Rojas *Brave New Unwired World, John* Wiley & Sons: 2002

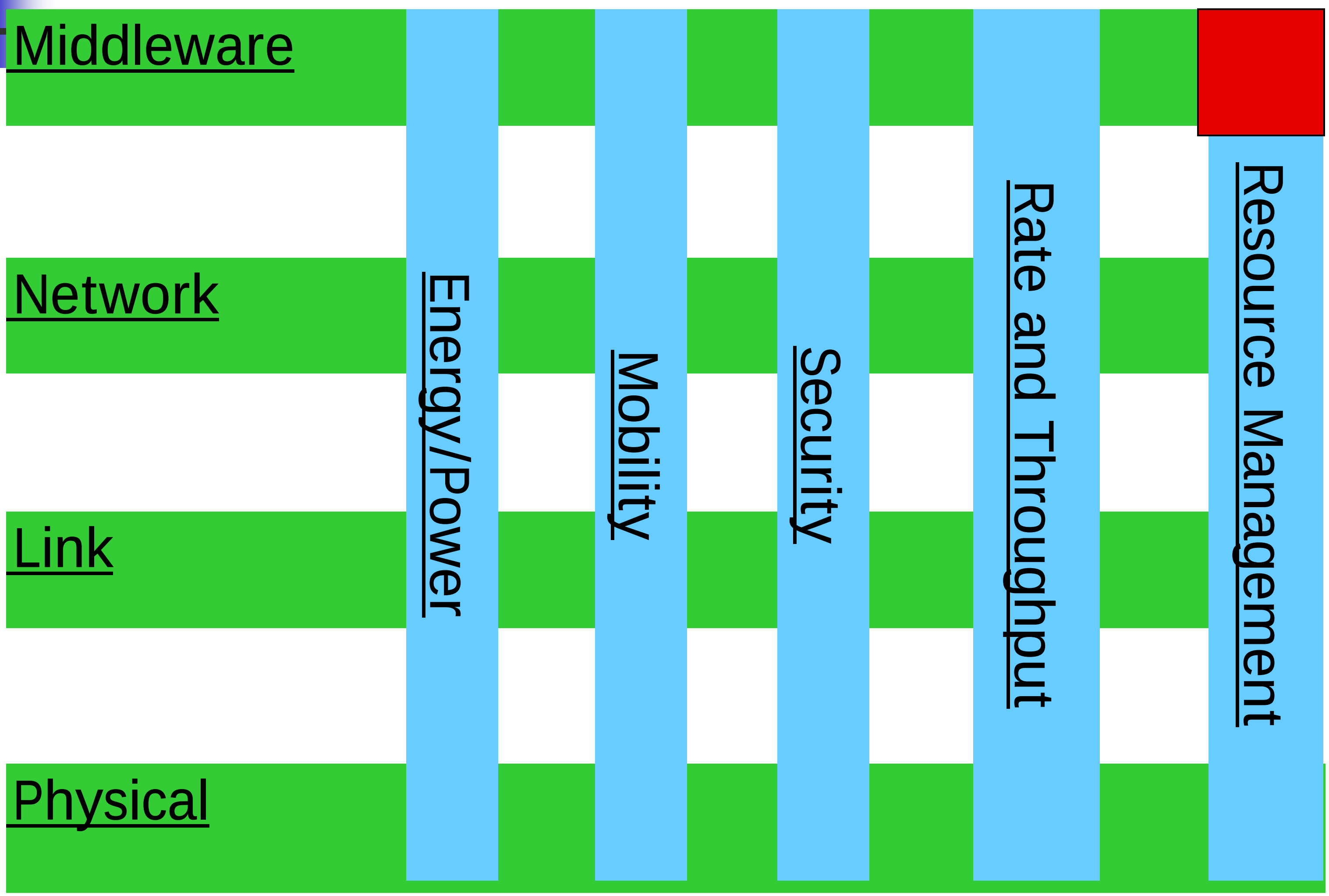
Low Mobility

Multimedia Services in Low Mobility



How to enable delivery of Internet-based multimedia documents with QoP guarantees in a resource-constrained and low mobility IEEE 802.11 environment?

Cross-Layer Issues

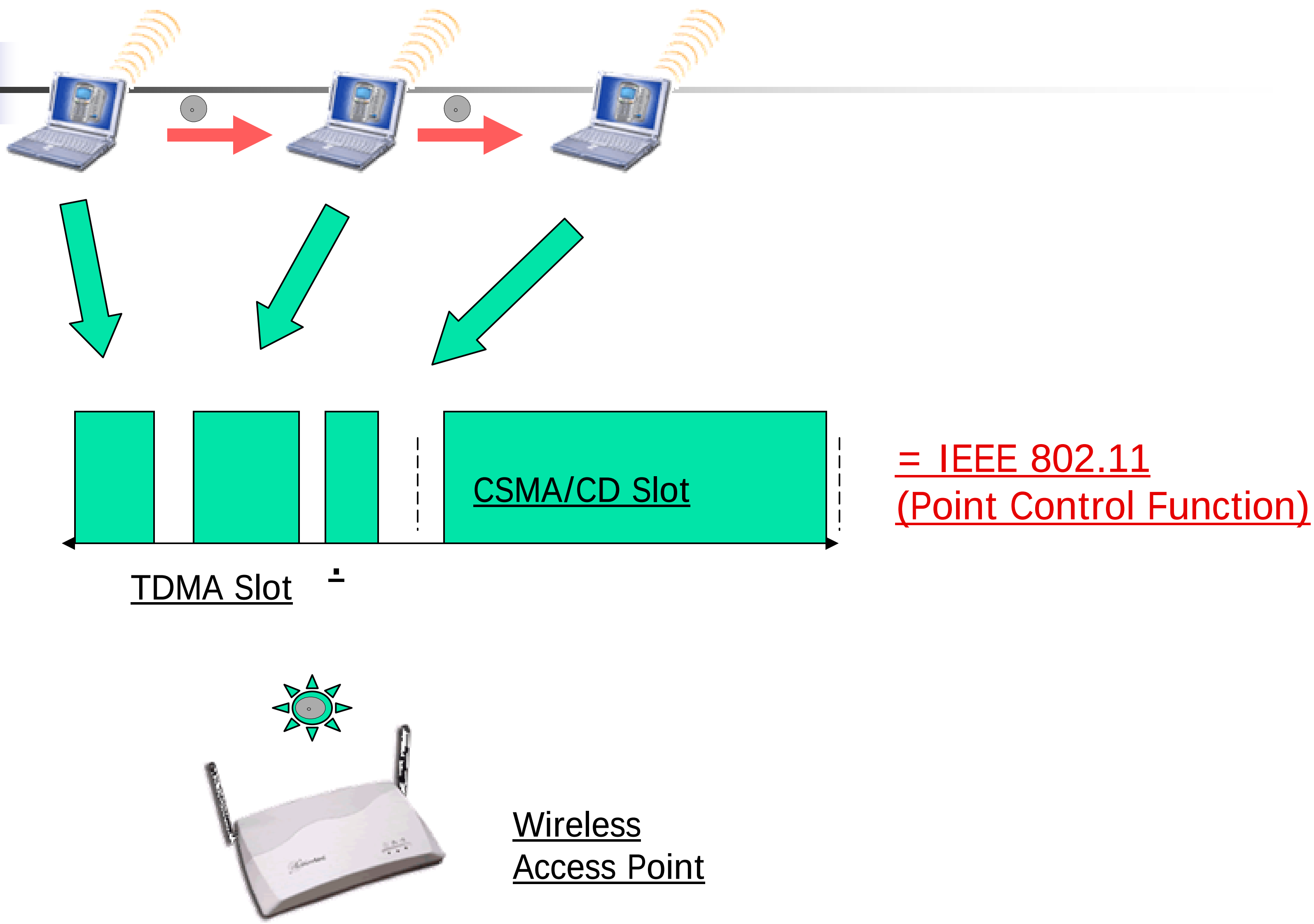


Resource Allocation policy

- Several QoP parameters can be used for developing resource allocation and admission control strategies for each component of the overall system, and in particular, for the middleware of WLAN. For example, reliability determines the acceptable level of data loss or degradation

- Allocation
  - Fair allocation: If quality needs to be degraded, then degradation is uniformly spread across all the users
  - Priority based allocation (class definition)

Overlay-Based Resource Aggregation (ORA) Approach (Middleware for Wi-Fi)



Experimental Evaluation of ORA Protocol

- Measurements for Jitter and transmission delays for media streams
- Results: low delay variations
- Increase in average transmission rate (25-30%)
- Reduction in average jitter delay (20 – 25%)
- For high speed LANs ORA scheme can provide a viable technology

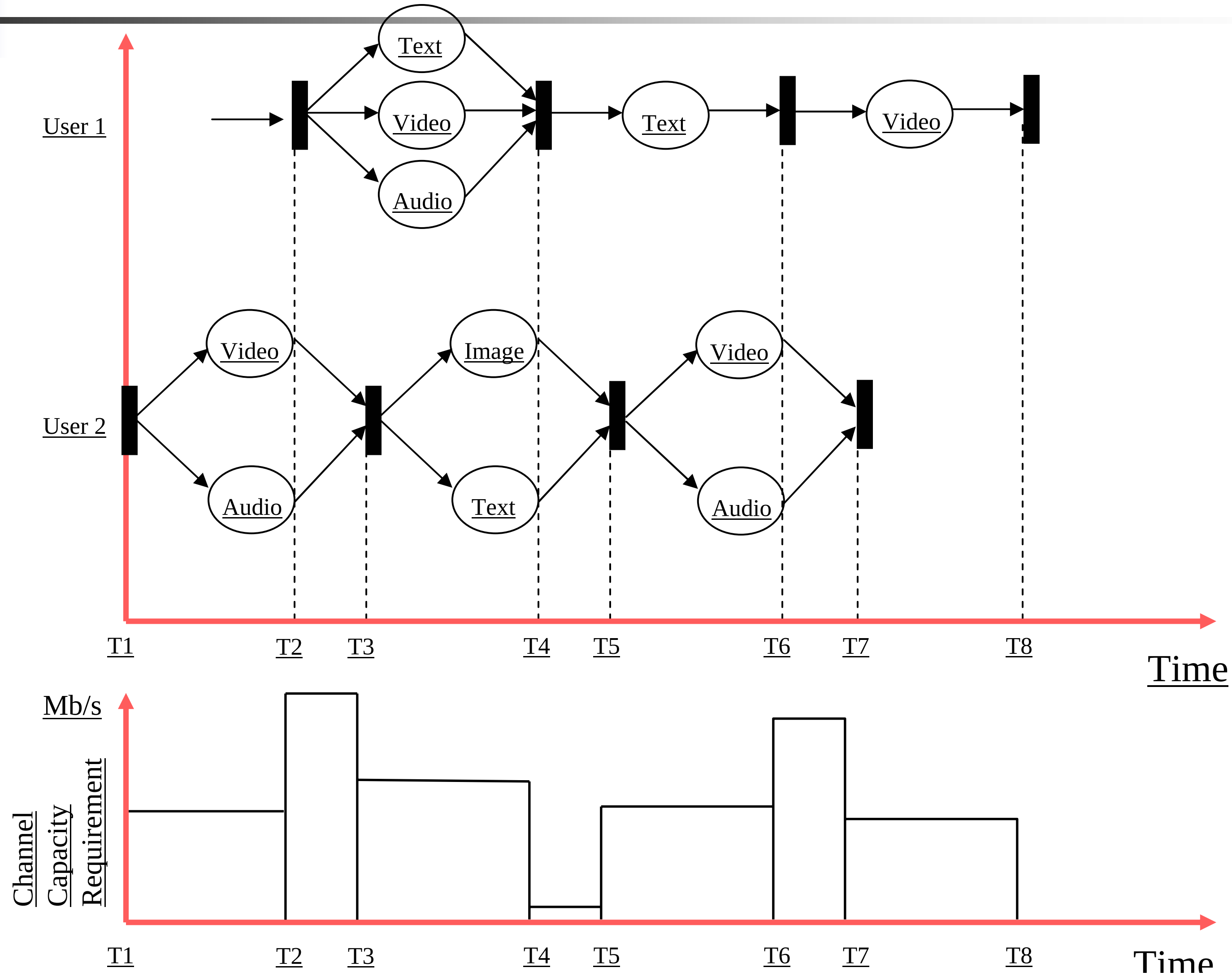
Table 1: Jitter Delays without TBM

Packet Size (bytes)	Rates (Mbps)	Delay (s)	Std. Dev. (s)	Variance (s)
1460	14.38	8.11e-04	8.94e-04	7.99e-07

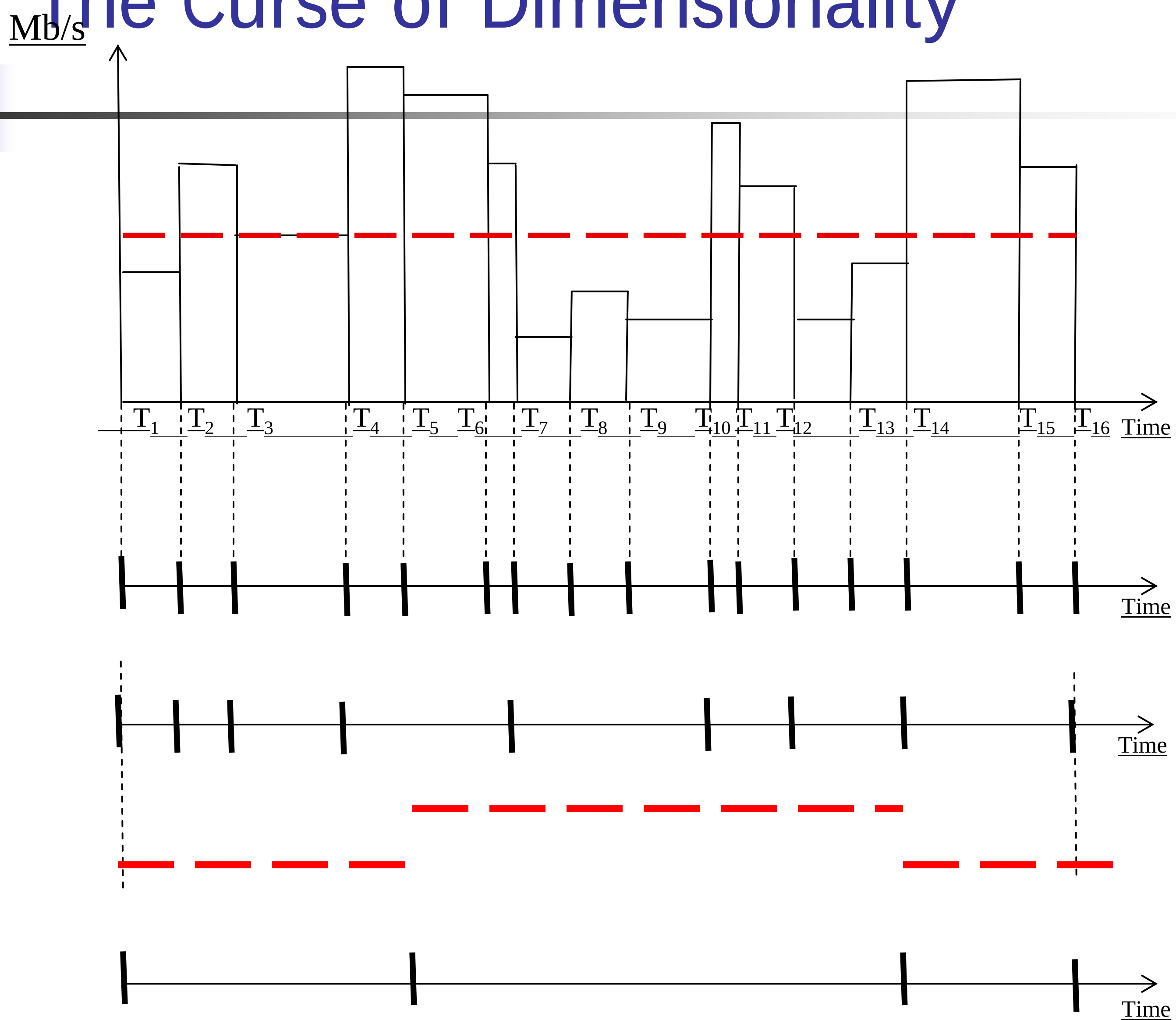
Table 2: Jitter Delays with TBM

Packet Size (bytes)	Cycle Time (ms)	Time Slot (ms)	Rates (Mbps)	Delay (s)	Std. Dev. (s)	Variance (s)
1460	200	150	18.47	6.44e-04	7.62e-04	5.80e-07
1460	200	100	16.79	6.61e-04	7.36e-04	5.41e-07
1460	150	100	18.12	6.33e-04	8.17e-04	6.67e-07

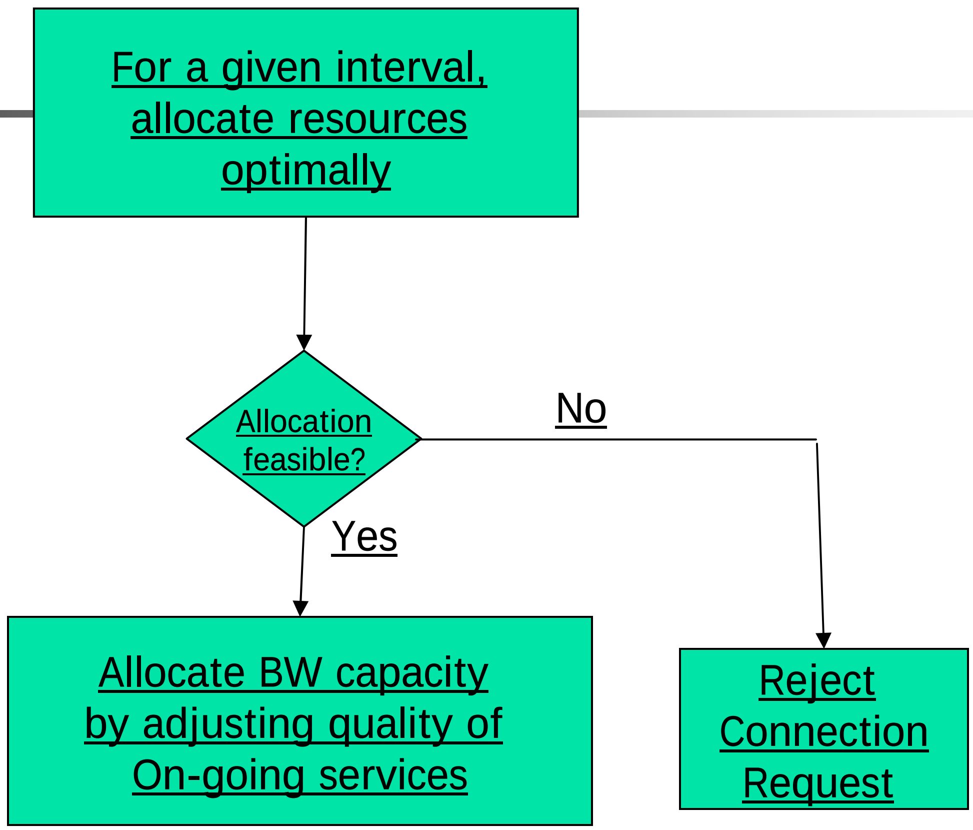
Resource Allocation Decision: Dealing with the multiplicity of users



Resource Allocation Decision:
The Curse of Dimensionality



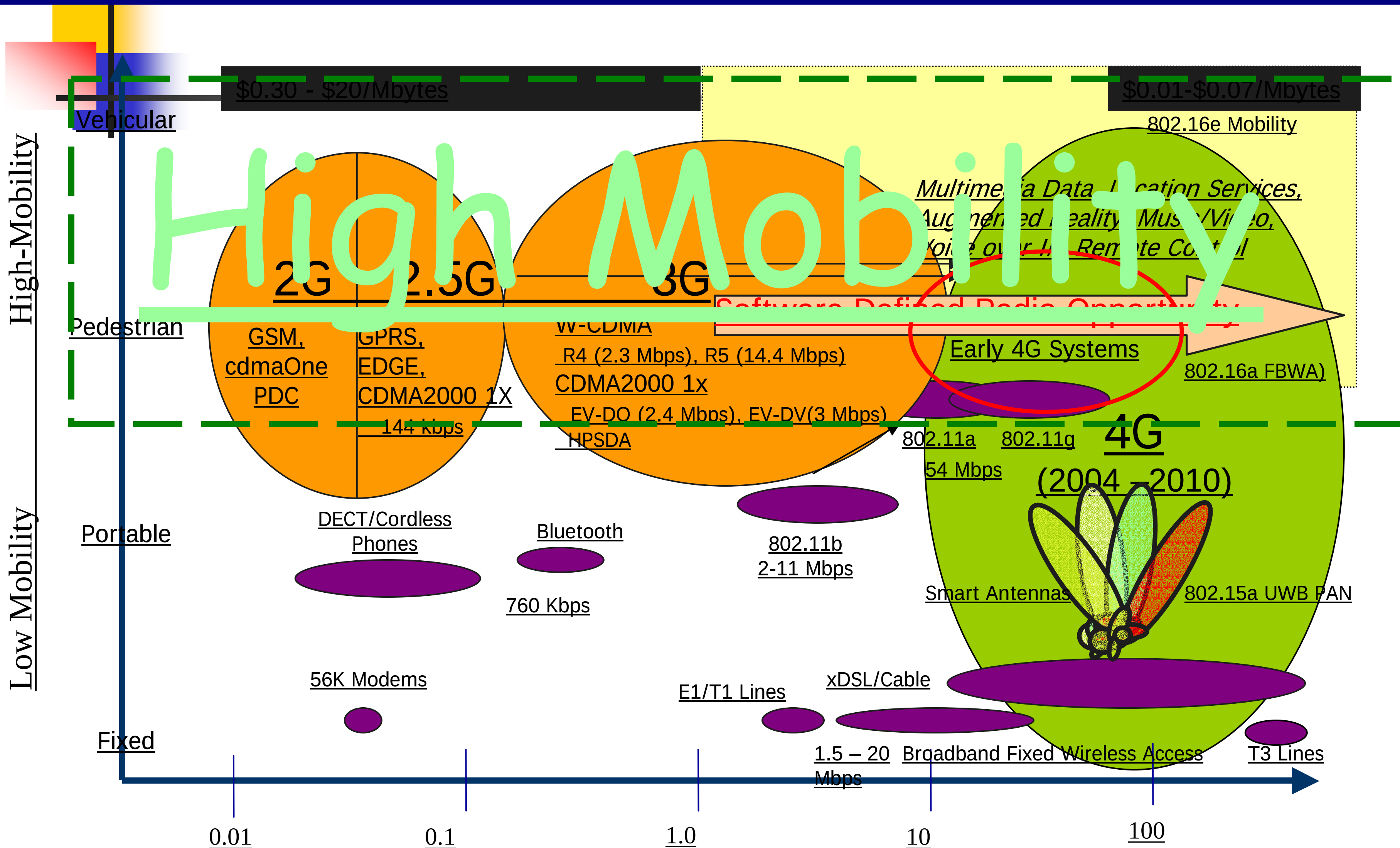
Resource Allocation and Admission Control Protocol



For multiple service classes, resource allocation can be prioritized.

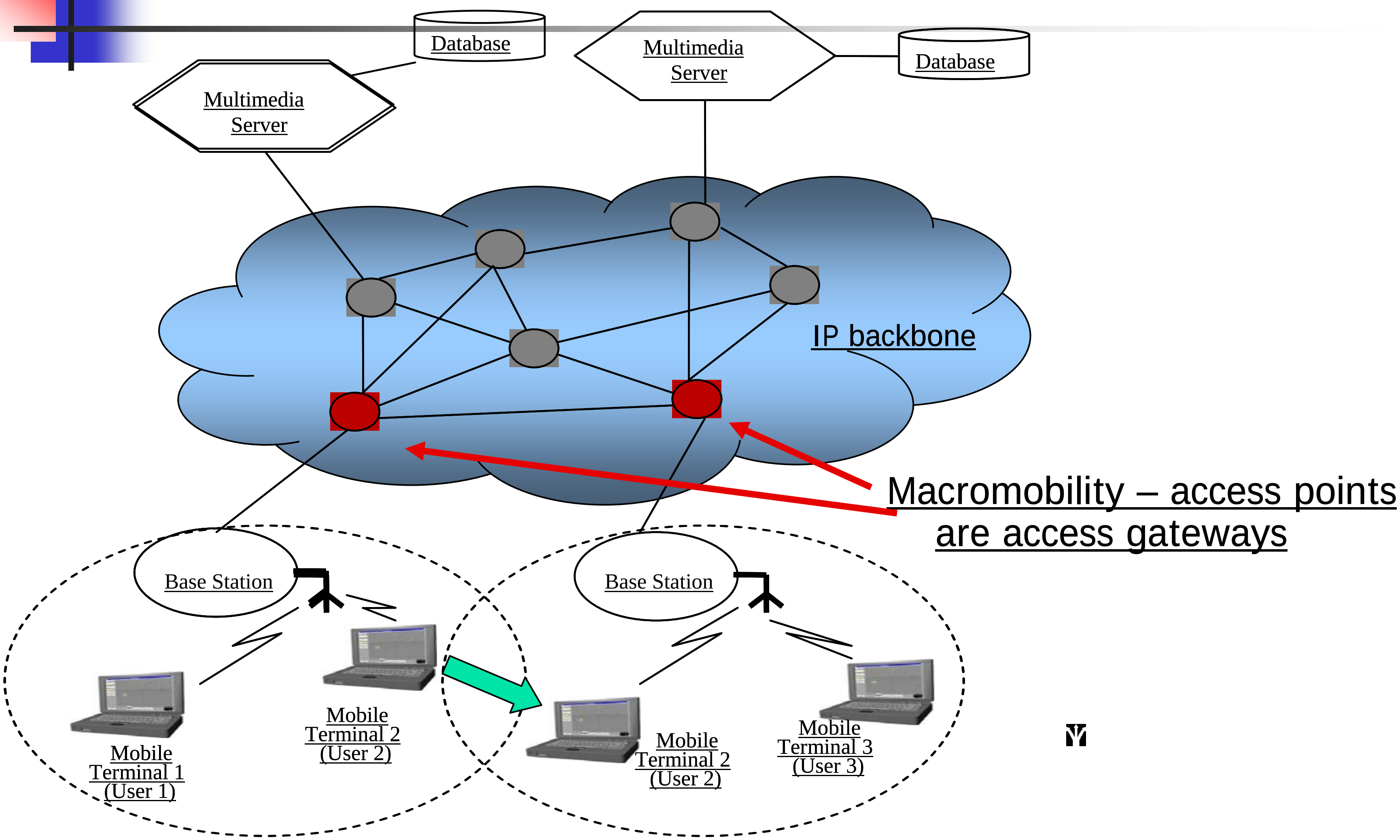
High Mobility

4G Wireless: >40-150 Mbps Transmitters



Source: Alex Lightman & William Rojas *Brave New Unwired World, John* Wiley & Sons: 2002

4G and IP-based High Mobility Multimedia Users



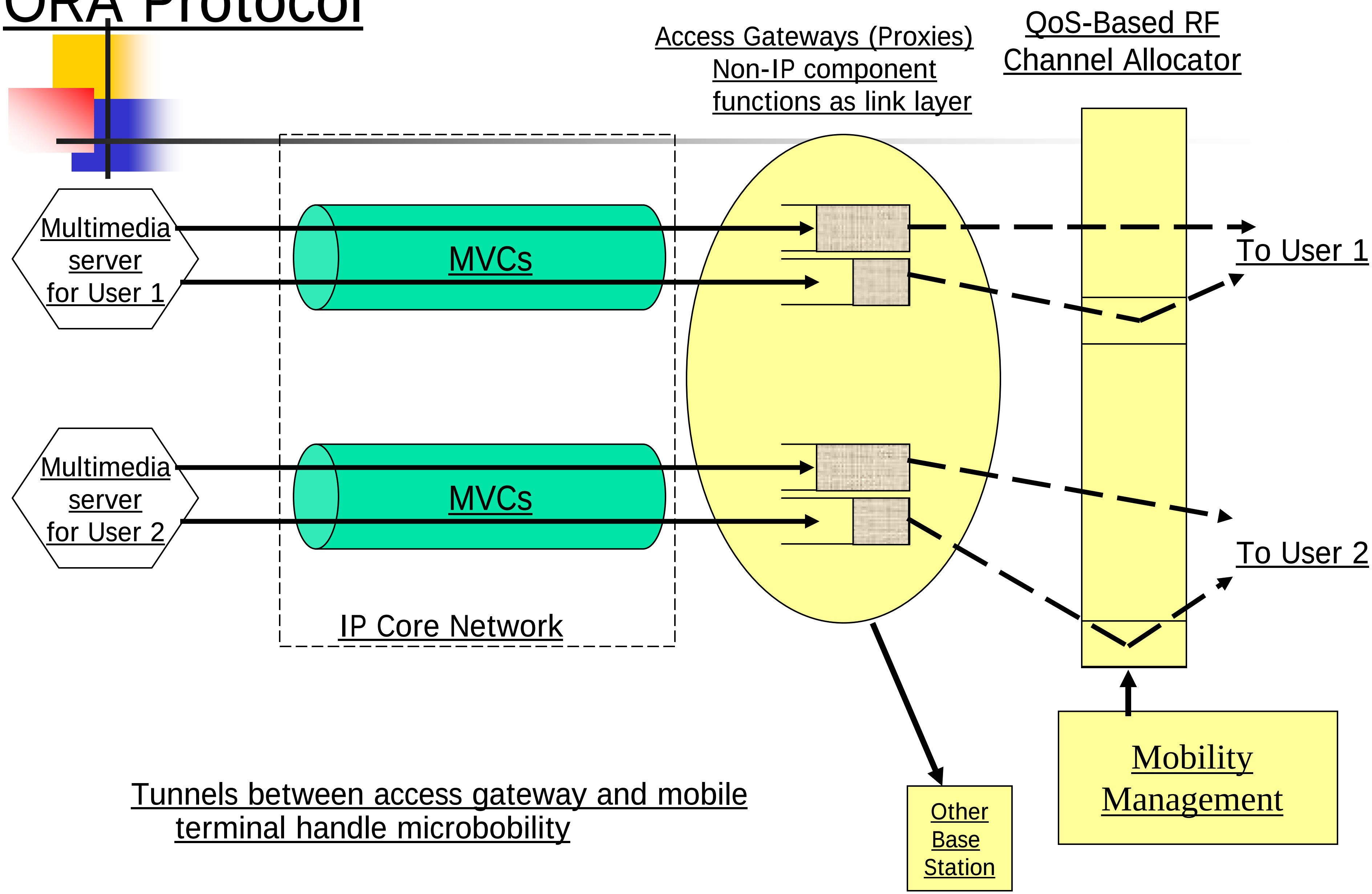
Resource Management in High Mobility

- Traffic load at base stations can change due to
  - Number of connections currently served
  - Changing level of concurrency of objects in a document
  - New connections
  - Hand-off connections

Challenges Associated with User Mobility

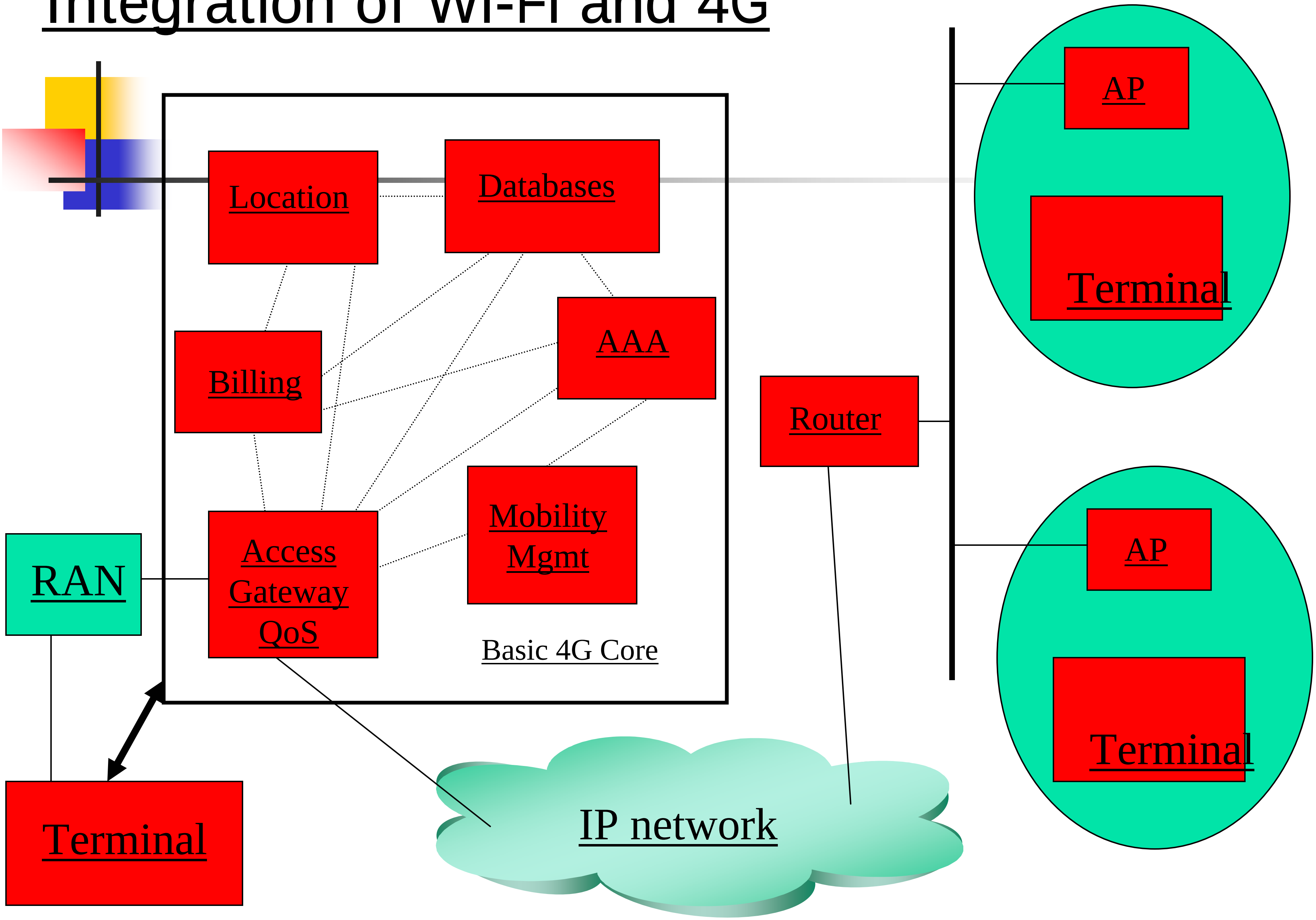
- Connection hand-off drops due to user mobility
- Advance resource reservation in all cells to be visited by a mobile user in order to avoid hand-off drops (requires mobility estimation of users)

4G – All-IP Mobile Wireless Access Infrastructure: ORA Protocol



Tunnels between access gateway and mobile terminal handle microbobility

Integration of Wi-Fi and 4G

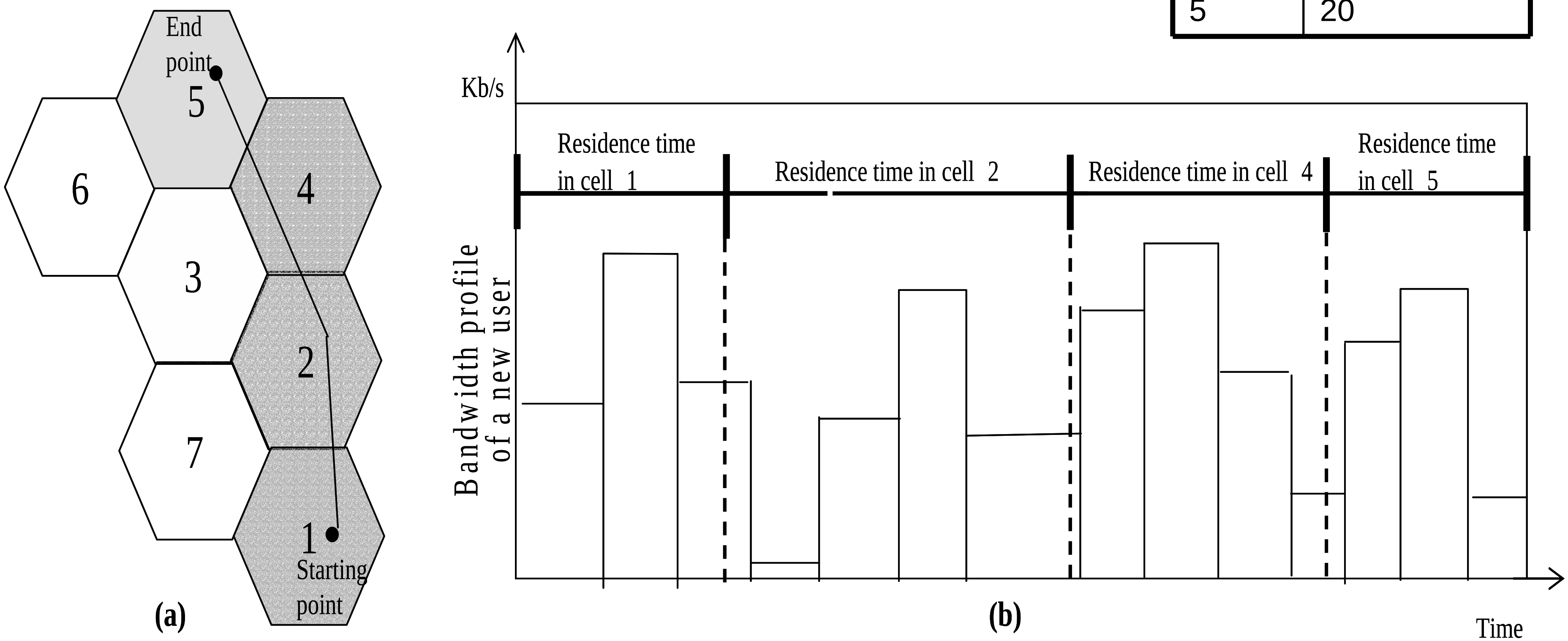


A Key Challenge in ORA: Matching Mobility and Document Profiles

(Shafiq et al, IEEE Communications, March 2003, pp: 131-145)

User's mobility profile

Cell Id	Estimated residence time in mins
1	18
2	36
4	24
5	20



(a) Predicted path of a mobile user. (b) Bandwidth profile of the mobile user in the predicted path.

Modeling User Mobility

(D. Hong and S. S. Rappaport, “Traffic Model and Performance Analysis for Cellular Mobile Radio Telephone Systems with Prioritized and Non Prioritized Procedures,” *IEEE Trans. Vehicular Tech., vol. 35, Aug. 1986, pp. 77–92.*)

- Assumption: A user provides his/her traveling path information at the time of connection request
- The arrival and departure times of a mobile user in each cell included in his/her traveling path can be estimated using a probability density functions of residency time T_R in a cell:

$$f_{T_R}(t)(\text{originating cell}) = \begin{cases} \dfrac{8R}{3V_{max}\pi t^2}\left[1-\sqrt{\left\{1-\left(\dfrac{tV_{max}}{2R}\right)^2\right\}^3}\right] & \text{for } 0 \le t \le \dfrac{2R}{V_{max}} \\ \dfrac{8R}{3V_{max}\pi t^2} & \text{for } t \ge \dfrac{2R}{V_{max}} \end{cases}$$

$$f_{T_R}(t)(\text{hand off cell}) = \frac{3}{2} f_{T_n}(t)$$

V_{max} is the maximum speed of the mobile user and *R* is the radius of the cell.

Resource Allocation for Cellular Environment

- At a base station on the travel path, &
- For each computed residency time
- Use local ORA allocation scheme

ORA Protocol

- For a new session, a user sends his/her mobility and document information to the Gateway of the current base station (BS)
- The Gateway determines the mobility profile of the user for the requested session and forward the connection request to all other Gataeways included in the mobility profile
- A Gateway included in the mobility profile of the user, tests the feasibility of the resource allocation problem for the residency time of the user corresponding to that cell
- Connection is accepted if allocation is feasible for at all the Gateways.

Resource Allocation Issues

- What if allocation is not feasible?
  - reject connection, or
  - run the resource allocation problem with a new set of reliability requirements
- How frequently the resource allocation procedure can be invoked?
  - at every transition of the multimedia document
  - at some selective transitions
  - at some fixed time period

These options need to be evaluated

Problem Formulation

- If $\gamma^{(k)} > C^{(k)}$ in the interval $I^{(k)}$, data needs to be dropped in that interval
- $\theta_i^{(k)}$, percentage of data dropped from the object $O_i^{(k)}$

Problem Formulation

Minimize $$\sum_{k \in M} \left(\sum_{i<j} \left(\theta_i^{(k)} - \theta_j^{(k)} \right)^2 \delta(I^{(k)}) \right)$$ (A)

Subject to $$\left(\sum_{i=1}^{n} \theta_i^{(k)} |O_i^{(k)}| - \left(\gamma^{(k)} - C^{(k)} \right) \right) \delta(I^{(k)}) = 0$$ (I)

$$0 \le \theta_i^{(k)} \le 1 - \omega_i^{(k)}, \qquad \text{for } i = 1, \ldots, n$$ (II)

$$\delta(I^{(k)}) = \begin{cases} 1, & \text{if } I^{(k)} \cap [T_d^{(k-1)}, T_d^{(k)}] \ne \phi \\ 0, & \text{otherwise} \end{cases}$$ (III)

$[T_d^{(k-1)}, T_d^{(k)}]$ are the interval points associated with residence time T_R in cell k of the mobile user.

Problem Formulation

- Constraints (I) and (II)
  - ensures that data degradation is spread across the objects in accordance with their reliability requirements
- Constraint (III)
  - states that resources for a given mobile user are only allocated in cell k for the time interval $I^{(k)}$, provided this interval overlaps with the user's expected residence time in cell k

Conclusion and Summary

- Resource management problem is formulated as an optimization problem based on reliability parameter
- Formulation can be expanded to include other QoP parameters as well
- Wireless resources can be allocated based on the solution to the NLP problem