HY537: Έλεγχος Πόρων και Επίδοση σε Ευρυζωνικά Δίκτυα

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Τμήμα Επιστήμης Υπολογιστών
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Διαδικαστικά

Περιεχόμενο και στόχος μαθήματος

Έλεγχος δικτύων - Βασικοί μηχανισμοί - Προβλήματα

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- Διδάσκων: Βασίλειος Σύρης (vsiris@csd.uoc.gr)
- Προαπαιτούμενα: HY335 Δίκτυα Υπολογιστών, HY217 Πιθανότητες
- Διδακτικές μονάδες 4, Θεματική περιοχή: Β
- Βοηθός: Χαρίτον Μελισσάρης
- Μαθήματα: Δευ. 3-5, Τετ. 3-5, Β211
- Σελίδα: http://www.csd.uoc.gr/~hy537 Πρόγραμμα διαλέξεων, υλικό σε ηλεκτρονική μορφή (διαφάνειες, αναφορές, κτλ.)
- Ηλεκτρονική λίστα: hy537-list@csd.uoc.gr

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- Διαλέξεις: ~ 10 εβδομάδες (~20 διαλέξεις), υπόλοιπες για παρουσιάσεις εργασιών
- Ασκήσεις: 4 σειρές
- Εργασία: Υλοποίηση & μελέτη μηχανισμού ελέγχου
  - Θα δοθούν υποψήφια θέματα: μηχανισμοί ελέγχου σε ενσύρματα και ασύρματα δίκτυα
  - Υλοποίηση του μηχανισμού ελέγχου σε προσομοιωτή (NS-2, MATLAB,Mathematica)
  - Βήματα:
    - Παρουσίαση προβλήματος (στην τάξη)
    - Υλοποίηση και εκτέλεση πειραμάτων
    - Τελική παρουσίαση (στην τάξη)
    - Αναφορά
- Συζήτηση στην τάξη
- Τελική εξέταση

HY537: Έλεγχος Πόρων και Επίδοση σε Ευρυζωνικά Δίκτυα

- Βαθμός:
  - 10% ασκήσεις
  - 50% εργασία
    - 20% δύο παρουσιάσεις & συμμετοχή σε συζητήσεις στην τάξη
    - 30% αναφορά
  - 40% τελική εξέταση (θα πρέπει βαθμός >= 4)

Σκοπός

- Εις βάθος μελέτη θεμάτων σχετικά με δικτυακές υπηρεσίες, και τις τεχνολογίες για παροχή αυτών
- Έλεγχος πόρων σε ενσύρματα (IP, ATM, IP-QoS) και ασύρματα (CDMA, Wireless LAN)
- Κατανόηση μαθηματικών μοντέλων & εργαλείων για μελέτη της απόδοσης δικτύων
- Εφαρμογή οικονομικών μοντέλων για έλεγχο συμφόρησης και πόρων
- Ο ρόλος της χρέωσης ως μηχανισμός ελέγχου δικτύων

Περιεχόμενα

- Βασικές αρχές ελέγχου δικτύων
- Δικτυακές υπηρεσίες & δικτυακές τεχνολογίες (IP, ATM, IntServ, DiffServ, MPLS)
- Περιορισμοί στα δίκτυα υπολογιστών – ισοδύναμο εύρος ζώνης (effective bandwidth)
- Οικονομικά μοντέλα και εφαρμογή τους για έλεγχο δικτύων
- Χρέωση υπηρεσιών εγγυημένης ποιότητας υπηρεσιών (guaranteed Quality of Service – QoS)
- Συμφόρηση: TCP, ECN, κ.α. και εξέλιξη μηχανισμών ελέγχου συμφόρησης, διαμοίραση πόρων, δικαιοσύνη
- Έλεγχος πόρων σε ασύρματα δίκτυα: CDMA, Wideband CDMA (3G), IEEE 802.11 (Wireless LAN – WiFi), IEEE 802.16 (WiMAX)

Υλικό - αναφορές

- Pricing for Communications Networks: technology, economics and modelling. Costas Courcoubetis and Richard Weber, Wiley, April 2003
- High-Performance Communication Networks, Second Edition. Jean Walrand and Pravin Varaiya, Morgan Kaufmann, 2000
- Ερευνητικά άρθρα από περιοδικά και συνέδρια

New advances and challenges

- Technological advances
- Deregulation of telecommunications market

- New highly competitive environment
- Both technology and economics play major role
  - Success note determined by technology alone
- Traditionally engineers devised services without reference to how they should be priced

Why pricing communications services is exciting

- Pricing affects ways services are used
- Communication contracts provide substantial flexibility, can be used for providing incentives
- Advances in network technology provide new possibilities for (economic) signaling on fast time scales
- Competition influenced by network architecture
- Communication services are goods that should be priced according to quality and performance

Role of economics

- Decentralized control mechanisms
  - Use price and congestion signals to provide incentives
- Engineering performance: in terms of utilization, delay, blocking, etc
- Economic efficiency: include the “value” that customers obtain from using the network
- Entities (users-customer, network) are rational, seeking to maximize there own benefit

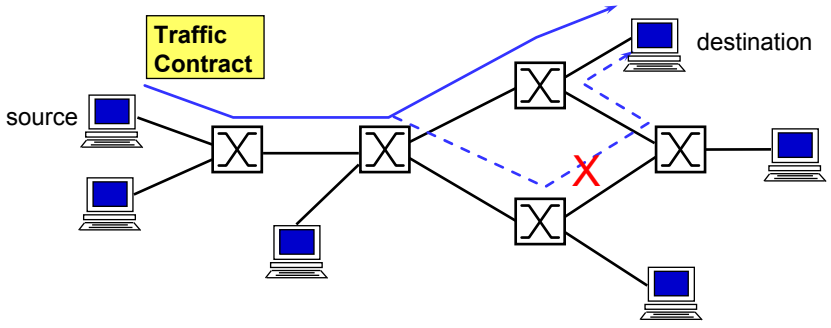
Network control for various service types

- ATM and IP supports statistical multiplexing
- Network control different for guaranteed and elastic services
- Guaranteed services
  - User-network contract
  - Call Admission Control - CAC
  - Open loop control
- Elastic services (TCP, ABR):
  - no CAC, except for MCR (Minimum Cell Rate)
  - Closed loop control

Time scales of network control

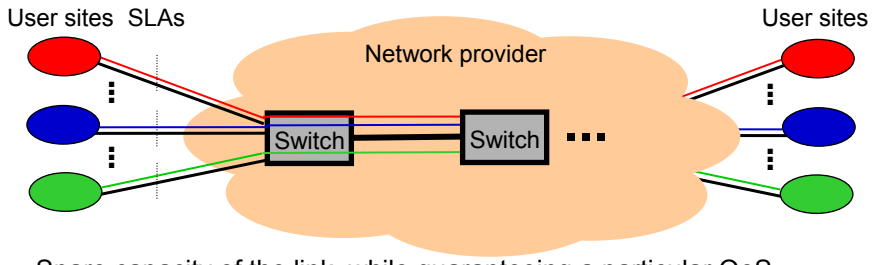
Traffic & Congestion Control Functions	Response time
Selective cell discard, frame discard, priority control and scheduling, Usage Parameter Control (UPC), traffic shaping	Cell time
Feedback controls	Round-trip propogation time
Routing, Call Admission Control (CAC)	Connection interarrival time
Network management control	order of minutes
Pricing	months, years

Routing and CAC



- **Routing**: find path from source to destination that fulfils user requirements (bandwidth, QoS)
- **Call Admission Control** (CAC): performed at every switch, determines whether there are enough resources to accept a call

Some Network Management Questions



- Spare capacity of the link, while guaranteeing a particular QoS (maximum delay or loss) ?
- Effect on QoS if one or more users are added ?
- How effective is traffic shaping ?
- Selection of traffic parameters of SLA (Service Level Agreement ?

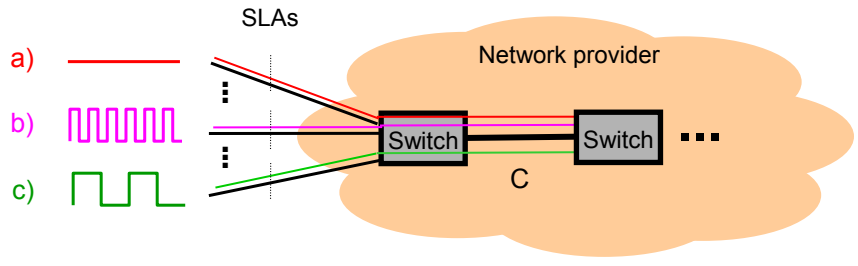
Possible Solution Approaches

- Use average load over large intervals (~minutes) ⇒ can lead to violation of QoS
- Use worst case scenarios (peak rate) ⇒ can lead to under-utilisation of resources
- Use traffic models ⇒ real world traffic not well approximated by traffic models
- ***Use actual traffic measurements and advanced statistical analysis procedures***

Simply Measuring Not Enough

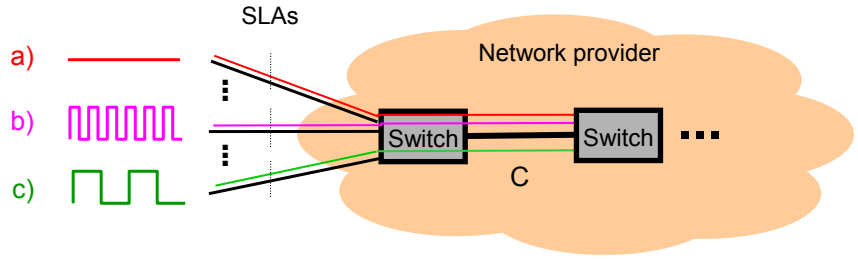
- Current technology can support traffic monitoring at very high speeds (> 10 Gbits/s)
- But, a huge amount of data is collected
- *What part of these measurements is important ?*
- *How can they be used for network management ?*

Example: Resource Usage



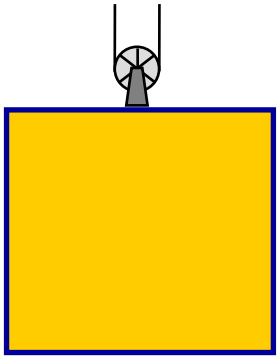
- All streams have same duration and volume
- What is the resource usage for each stream ?
- ➔ Answer: Depends !
  - Small link capacity C: a<b,c

Example: Resource Usage

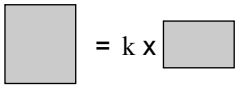


- All streams have same duration and volume
- What is the resource usage for each stream ?
- ➔ Answer: Depends !
  - Small link capacity C: a<b,c
  - Medium link capacity C: a=b<c
  - Large link capacity C: a=b=c

Loading an Elevator with Boxes



- What is the **relative effective usage** of a box ?
- Equivalently, in what sense



w_1, v_1 w_2, v_2

or $\alpha_1 = k \times \alpha_2$

W_{max}, V_{max}

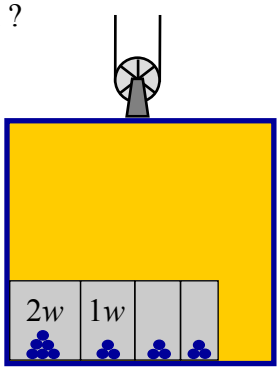
Key notion: substitution

Loading an Elevator (cont.)

- What is the relative effective usage of a box ?
  - Depends on which constraint is active: *max. weight* or *max. volume*
  - Determined by operating point
- If *max. weight* is active, then effective usage equals box's *weight*

$$\sum_i w_i = W_{\max}$$

$$\sum_i v_i < V_{\max}$$



$W_{\max}$, $V_{\max}$

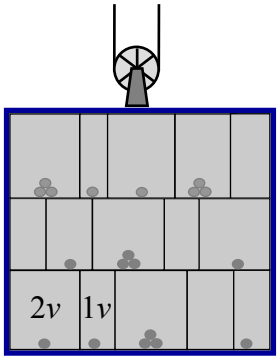
- **Effective bandwidth = weight**

Loading an Elevator (cont.)

- If *max. volume* is active, then effective usage equals box's *volume*

$$\sum_i v_i = V_{\max}$$

$$\sum_i w_i < W_{\max}$$



$W_{\max}$, $V_{\max}$

- **Effective bandwidth = volume**

Loading an Elevator (cont.)

- What is the relative effective usage of a box ?
  - Depends on which constraint is active: *max. weight* or *max. volume*
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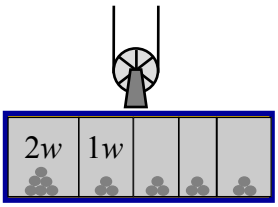
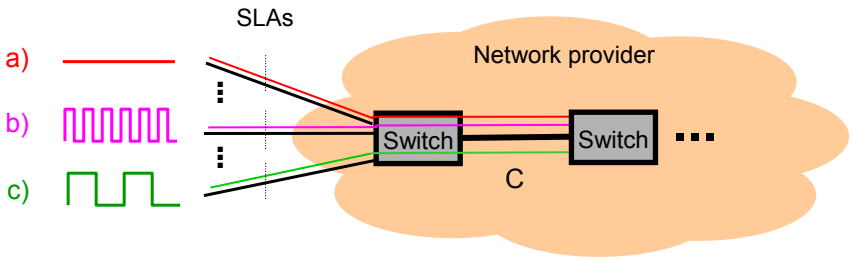


- **Effective bandwidth = ~~weight~~ = volume**

Example: Resource Usage



- Identification of important ***time scales*** indicate what to measure
  - *individual packet traces* can be *overly detailed*
  - aggregate load in intervals with duration a few *10s milliseconds* can be sufficient
  - time scales depend on *network resources* and *traffic mix*

Quantifying resource usage

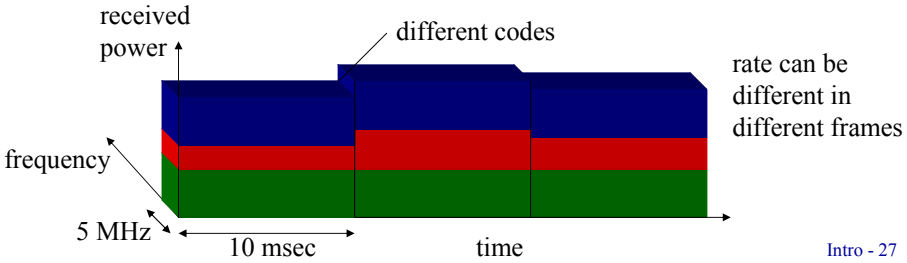
- Resource usage depends on technology
  - Circuit switched networks: circuit with fixed capacity reserved for whole duration of connection
  - Packet switched networks: no static bandwidth reservation
- Resource usage depends on guarantees
  - No guarantees => resource usage = average rate
  - Strict guarantees => resource usage close to peak
- Contracts or Service Level Agreements (SLAs) are multidimensional quantities

Resource control in wireless networks is a challenge !

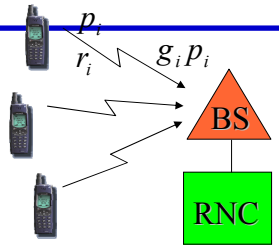
- Wireless channel is a shared medium: similar to legacy Ethernet CSMA/CD, but with key differences
- Wireless transmit to the wireless channel directly, no central point through which all traffic goes through
  - Can or cannot have central control
- Attenuation in the wireless medium
  - Location-based contention
  - Simple carrier sensing not enough
  - Can't perform collision detection
- Power is an important resource, influences interference
- Only recently there are mechanisms for supporting QoS (802.11e)

CDMA (Code Division Multiple Access)

- Wideband CDMA (WCDMA) most widely adopted 3G air interface
  - Based on Direct Sequence CDMA (DS-CDMA)
- Signals from different mobiles separated based on unique codes
- Transmission rate can change between frames



Resource usage in CDMA: Uplink



RNC: Radio Network Controller

target bit energy to noise density ratio E_b/N_0 (determines bit error rate)

spreading bandwidth

received power

$$\gamma_i = \frac{W}{r_i} \frac{g_i p_i}{\sum_{j \neq i} g_j p_j + \eta}$$

rate

interference + noise

assuming perfect power control

uplink is ***interference-limited***

resource constraint in uplink

$$\sum_i \frac{1}{\frac{W}{r_i \gamma_i} + 1} < 1$$

resource usage in uplink

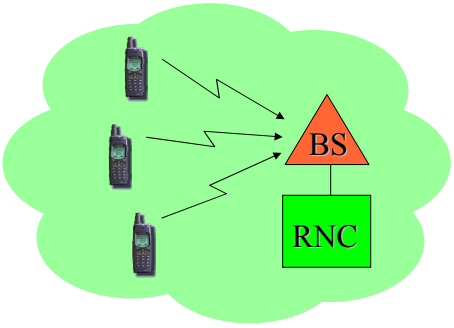
$$\frac{1}{\frac{W}{r_i \gamma_i} + 1}$$

approximations for large # of mobile users

$$\sum_i r_i \gamma_i < W$$

$$r_i \gamma_i$$

WCDMA (3G)



- Simultaneous transmissions from mobiles possible
  - Differentiated based on code
  - CDMA: multiple access protocol

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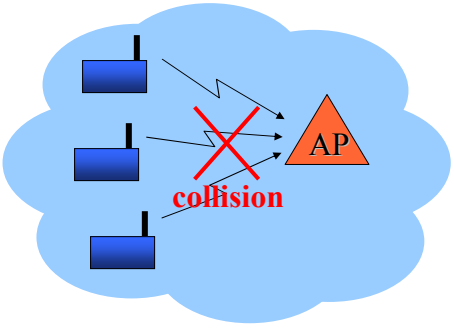
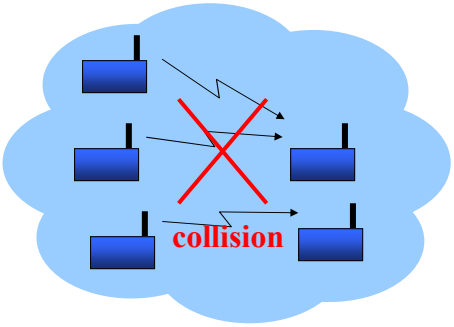
WLAN (802.11)



- Simultaneous transmissions not possible
- With DSSS (Direct Sequence Spread Spectrum): same code used for all transmissions
- MAC (CSMA/CA) controls access/contentions to shared medium

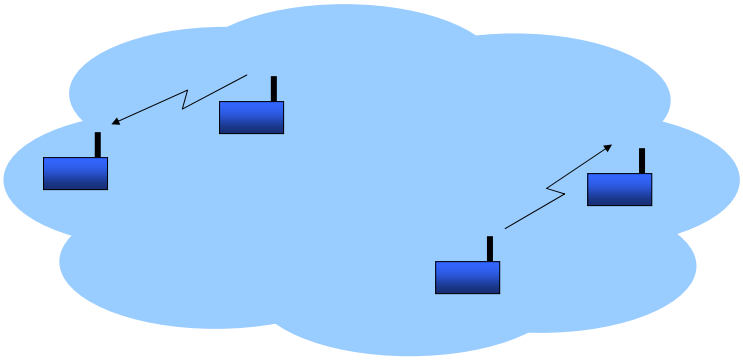
Intro - 30

WLAN (802.11): Ad Hoc



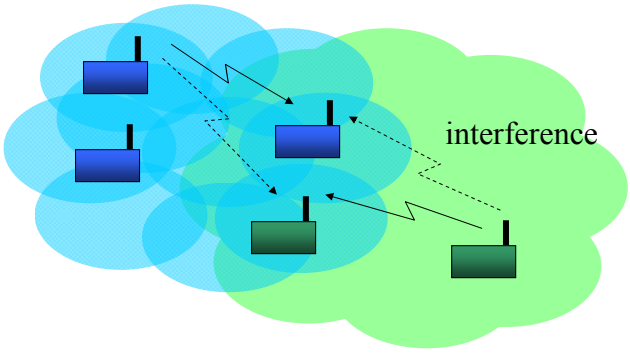
- Same with ad hoc configuration: Simultaneous transmissions not possible
- But…

WLAN (802.11): Spatial reuse



- Limited coverage due to path loss ⇒ location dependent contention
- Simultaneous transmission for distance groups (spatial reuse)
- Capacity of ad hoc network depends on topology

Multiple WLANs



- Simultaneous transmissions in different WLANs possible, even in close proximity
- Interference between WLANs
- 802.11a: supports dynamic channel selection and transmit power control (TPC)

Technologies

- WCDMA (3G)
  - Extension/refinement for loss sensitive
  - Extension for power of control channels
  - Investigation of transient operation via simulation
- Intra-WLAN
  - Technology: CSMA/CA (no CD), ACK, RTS/CTS
  - Service differentiation: thruput & delay, control parameters
  - Marking: measured load/congestion, sample path
  - Path loss results in limited coverage
  - Capacity depends on topology
- Inter-WLAN
  - Power control to adjust quality,coverage, and interference between WLANs
  - Bargaining solutions ?

Possible solution approaches

- Use average load over large intervals (~minutes) ⇒ can lead to violation of QoS
- Use worst case scenarios (peak rate) ⇒ can lead to under-utilisation of resources
- Use traffic models ⇒ real world traffic not well approximated by traffic models
- *Use actual traffic measurements and advanced statistical analysis procedures*