Social Sharing of Connectivity Resources: Control and Encouragement of Unselfishness in Mobile Environments

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8.9.2009 - MobiMedia '09

Agenda

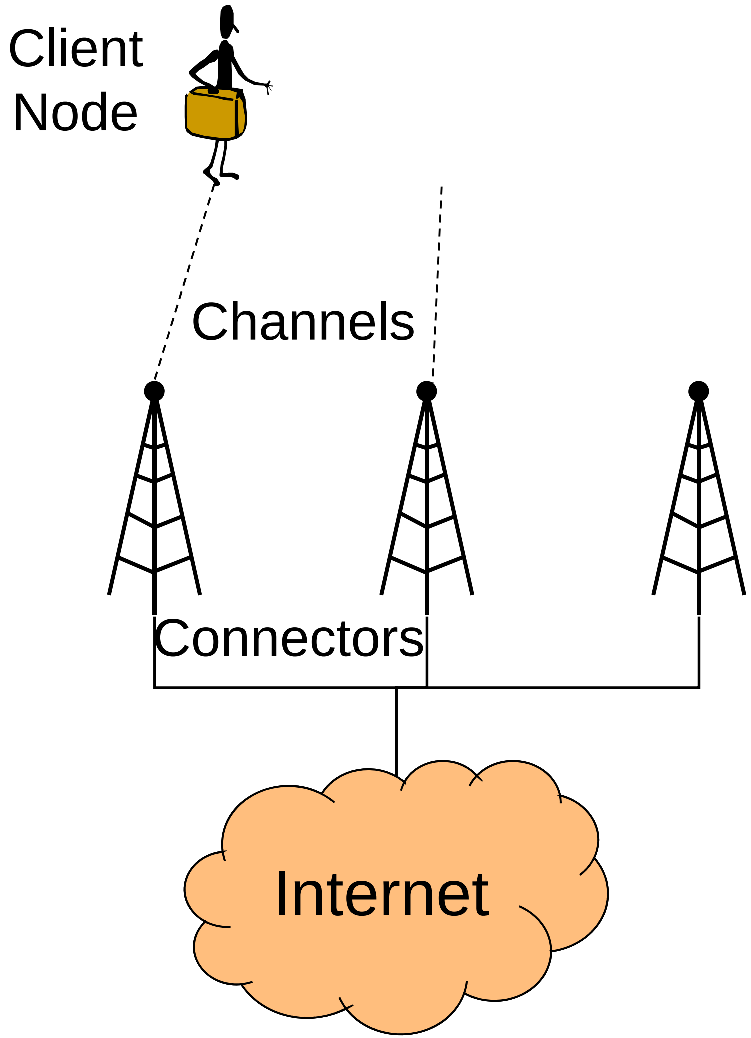
- From traditional homogeneous to novel **heterogeneous** wireless scenarios based on **node cooperation**
  - several communication technologies
  - infrastructure and **peer** points of access
  - **Internet** connectivity **sharing** and **peer-to-peer service** provisioning

- **Multi-hop Multi-path Heterogeneous Connectivity (MMHC)** middleware for **context-aware** dynamic connectivity in **heterogeneous environments**
  - **context information:** node mobility, path throughput, energy availability
  - push for **social sharing of connectivity** resources
    - provide connectivity **effectively**
    - **support fairness** in resource exploitation

The Wireless Scenario

- **Client** node: node **requiring** connectivity, e.g., user PDA
- **Connectors**: nodes **providing** connectivity, e.g., UMTS base station
- **Channel**: active client-connector IP connection, e.g., Bluetooth pairing and DHCP configuration

- **Handover procedure**
  - a client node **changes** current **connector** while moving
- **Evaluation process**
  - **context gathering**: which information is important?
  - **metric application**: which is the most suitable connector?

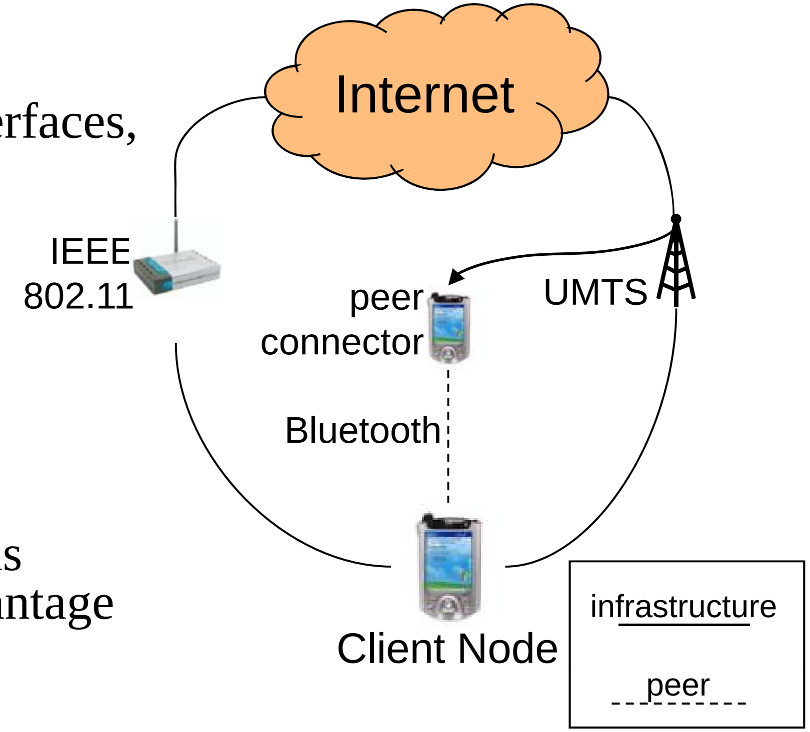


Traditional Homogeneous Wireless Scenario

- **One** communication **interface** at a time
  - the client node does not change wireless interface
- **Horizontal handover**
  - infrastructure connectors only
  - origin and destination connectors based on the same wireless technology
- IEEE 802.11
  - connectors are IEEE 802.11 Access Points (APs)
  - metric based on Received Signal Strength Indication (RSSI) and Signal to Noise Ratio (SNR), usually embedded in interface firmware

Cooperative Heterogeneous Wireless Scenario

- **Heterogeneous interfaces**
  - the client node exploits **multiple wireless** interfaces, even simultaneously
- **Heterogeneous connectors**
  - **infrastructure** or **peer** nodes
  - fixed or **mobile** peers
  - single-/**multi-hop paths**
- **Connectivity management**
  - managing interfaces/connectors/channels/paths considering **several context data** to take advantage of the **many networking opportunities**



- Heterogeneity and **node cooperation increases** client node **capabilities**:
  - heterogeneous connectors enable the **most suitable** form of connectivity
    - Bluetooth to limit power consumption, IEEE 802.11 to get larger bandwidth
  - peer connector **cooperation extends connectivity** opportunities via multi-hop **paths**
    - UMTS link accessed via Bluetooth through a peer connector

MMHC: Multi-hop Multi-path Heterogeneous Connectivity

- Novel metric considering a wide set of information at **different abstraction levels**
  - traditional RSSI/SNR based evaluation processes are not enough

- **Evaluation metric** specifically designed for heterogeneous wireless scenarios
  - client node and peer **mobility** (based on RSSI) to provide **reliability**
  - wireless technology and path characteristics, e.g., bandwidth and number of clients at each hop, to provide **sufficient throughput**
  - **residual battery** level to ensure path **long-term durability**

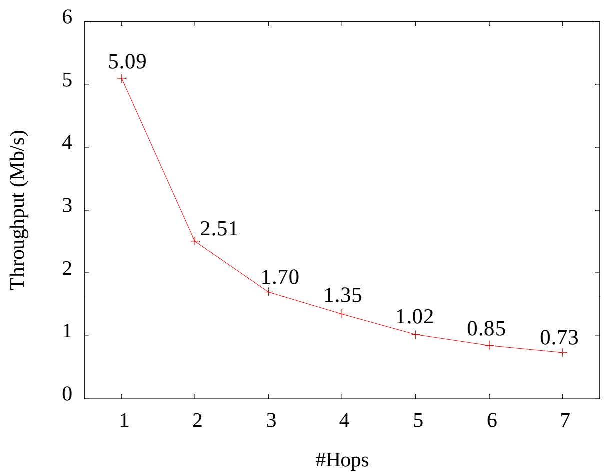
Social Sharing of Connectivity Resources

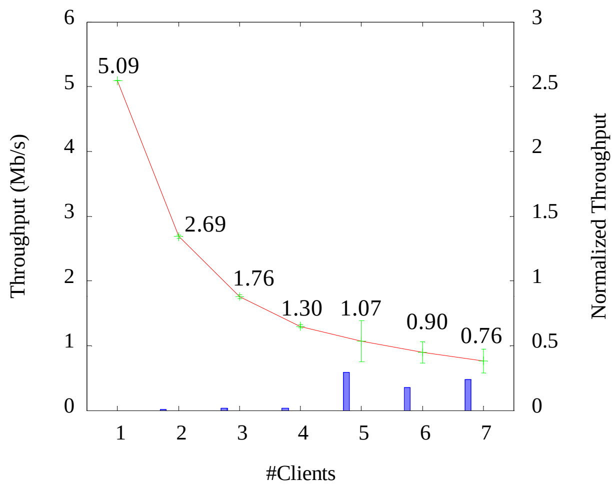
- Users are generally **willing to collaborate**
- Specific topologies and traffic patterns may dramatically **reduce** actual **performance**

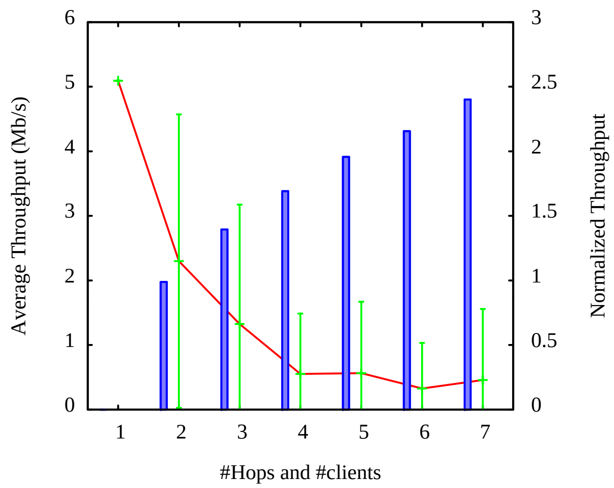
- **Effective** connectivity support
  - **avoidance of starvation** suffered by nodes distant from the wired Internet
- **Fair** sharing of connectivity resources
  - **not harming peer connectors** due to traversing traffic overload
  - **bandwidth** of clients in relation to their **behavior**: push for cooperative behavior

Performance Considerations

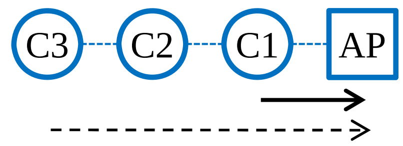
- Maximum throughput in multi-hop paths depends on wireless technology, number of **hops** and number of **clients**
  - clients of the same connector achieve almost the **same bandwidth** despite their actual behavior
  - Estimated Throughput (ET) to compare available paths







- Possible **starvation** in case of **concurrent requests** of intermediate connectors
  - most bandwidth to the nodes closest to the wired Internet



Effective and Fair Sharing: Guidelines

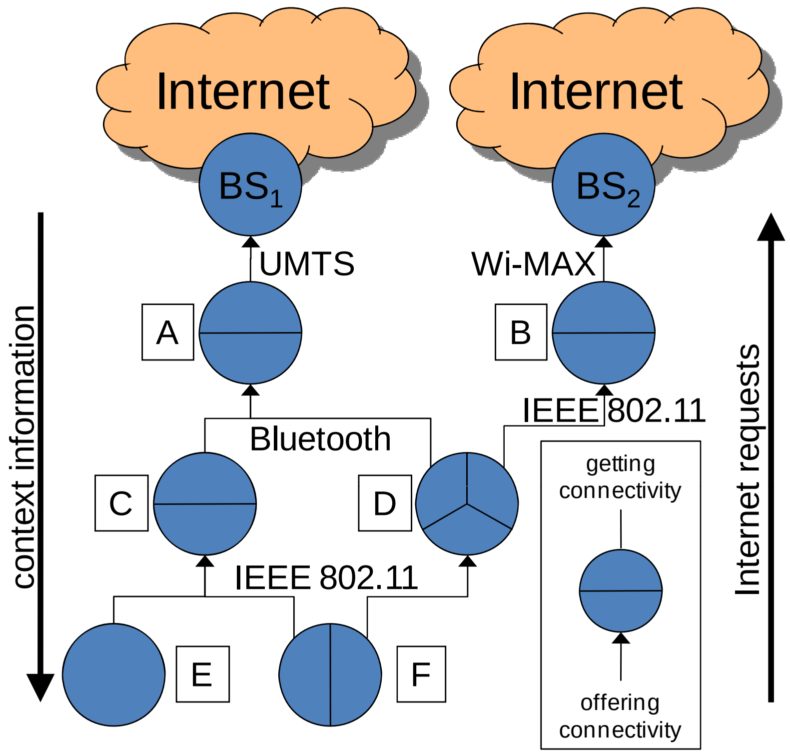
- Social sharing demands for both connectivity **effectiveness** and **fairness**
  - lightweight solution, even if with lower accuracy

- **Monitoring** of context information
  - actively **discriminate** among selfish and cooperative nodes
  - identify possible **starvation**
- **Active control** of node behavior
  - **share the load**: avoid overloading peer connectors with traversing traffic
  - **reward cooperative nodes**: clients behaving as peer connectors should be rewarded with larger bandwidth

Fairness Management in MMHC Environment

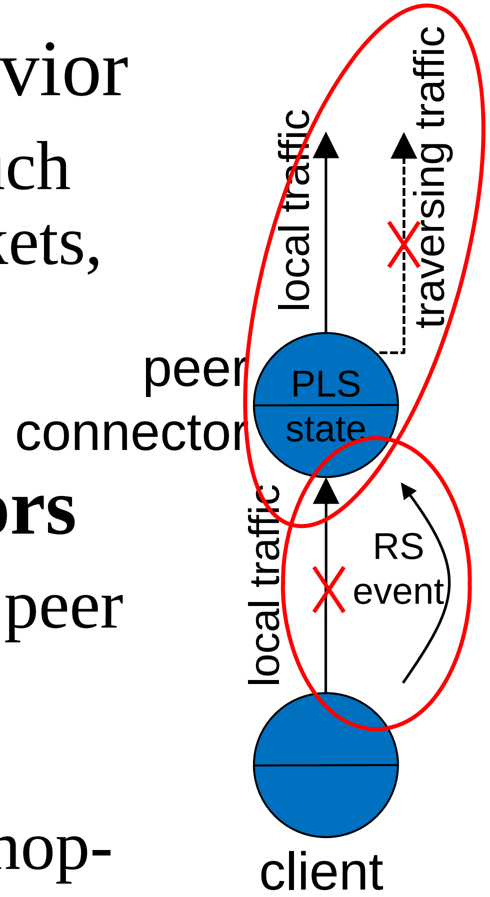
- Current Scenario
  - top-down context information
  - bottom-up Internet connectivity

- **Social** Scenario
  - time/hop-bounded peer-to-peer service discovery/invocation
  - **runtime monitoring** of achieved performance
  - **bottom-up starvation notification**
  - example
    - node F accesses BS_2
    - node D saturates bandwidth
    - node F notifies the misbehavior
    - node D reserves some bandwidth to node F



Fairness Management with Regional Scope (1)

- **Local monitoring** to estimate node behavior
  - **periodic gathering** of network **statistics**, such as locally generated packets, traversing packets, failed outgoing packets



- Context information to **one-hop neighbors**
  - **Possible Local Starvation** (PLS) state on a peer connector whenever there is **no traversing traffic**
  - **Remote Starvation** (RS) event sent to one-hop-distant peer connectors whenever most of the client **outgoing packets fails**

Fairness Management with Regional Scope (2)

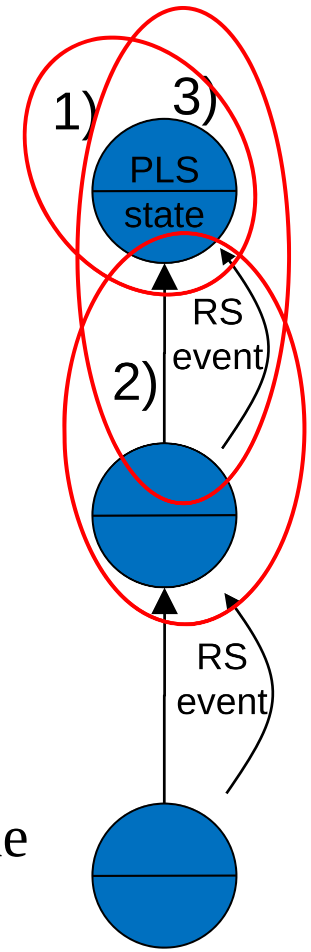
- Three different conditions

  1) **only PLS**: notification to the user of possible misbehavior, eventually ignoring the notification

  2) **only RS**: RS event **propagated to upper nodes**, since client starvation not performed by the local peer connector

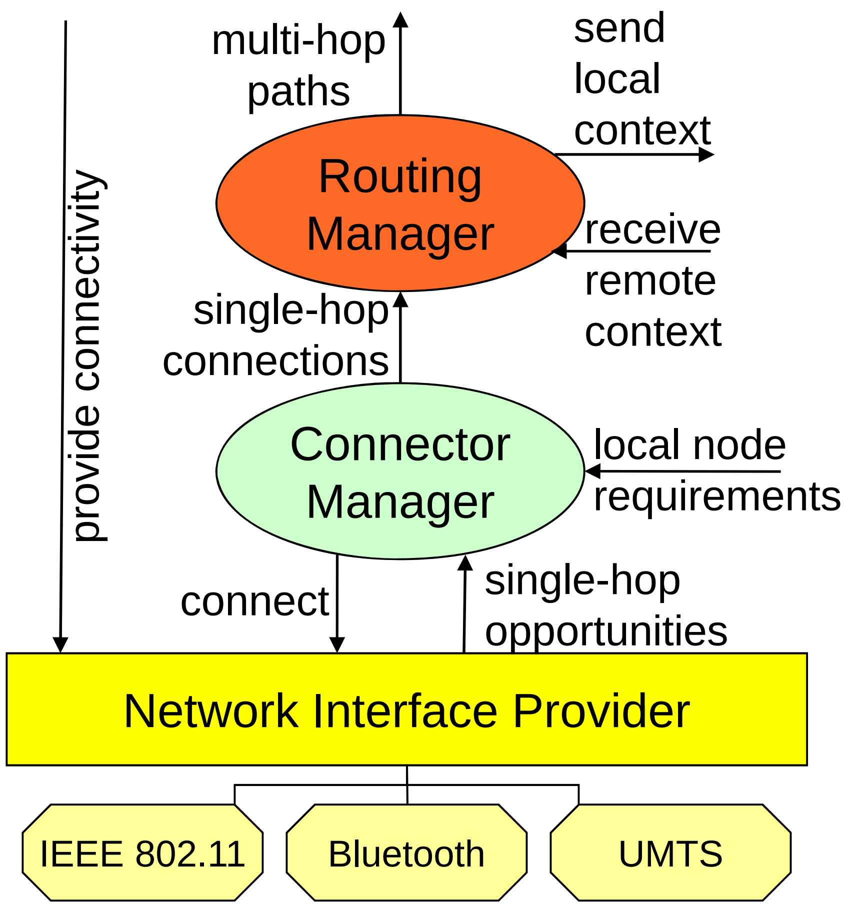
  3) **PLS + RS**: Local Starvation (LS) event requiring to **modify local bandwidth** reservation policy

    - **favor traversing** traffic instead of locally generated one
    - **favor** most **cooperative** clients



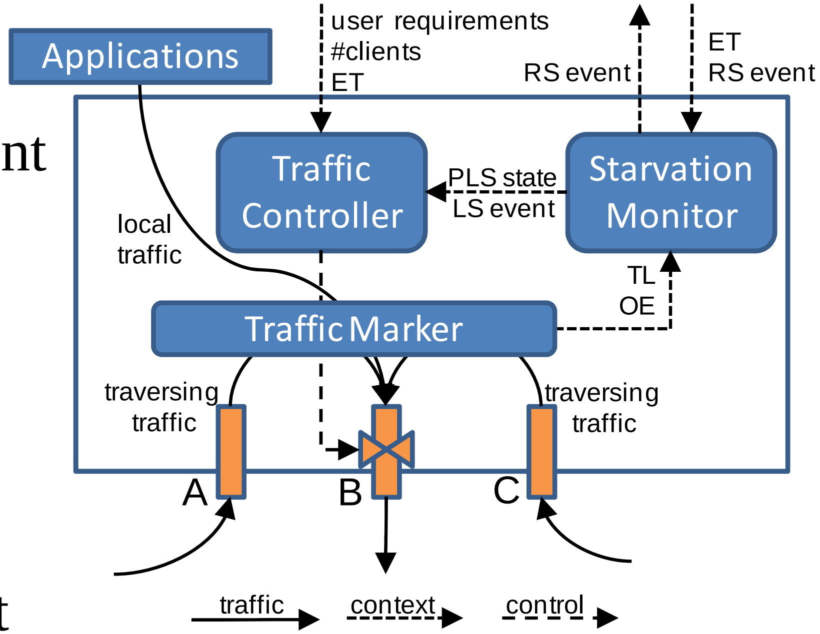
MMHC Architecture

- Network Interface Provider
  - **homogeneous access to heterogeneous interfaces** on different operating systems
- Connector Manager
  - **single-hop connections** based on node mobility
- Routing Manager
  - context information **remote distribution**
  - **multi-hop paths** based on estimated connectivity availability and throughput



Fairness Management Component

- Traffic Marker
  - marks and **monitors** locally generated and traversing packets
  - Traversing Load, **TL**: traversing and local packets ratio
  - Output Effectiveness, **OE**: correctly sent and generated local packets
- Starvation Monitor
  - **rises** (lowers) **PLS** state if TL<0.05 (>0.25)
  - **triggers RS** event if OE<0.05
  - **triggers LS** event if PLS active and received RS event from a remote client
- Traffic Controller
  - actively **manages local bandwidth reservation policy** to recover from starvation



Implementation Insights

- Traffic Marker
  - `iptables mark` to tag traffic packets
  - **per-client tagging** exploiting `input`, `forward` and `output` chains of the `mangle` table
- Starvation Monitor
  - **regional** fairness management via **context-aware RS event propagation** (no indiscriminate multi-hop event flooding)
- Traffic Controller
  - `tc` command whenever a client joins/leaves the network
  - $bw_L = ET*(1-RB)$ (local peer connector)
  - $bw_{Ci} = w_{Ci}*(ET*RB)$ (remote clients) where $\sum_{Ci} w_{Ci} = 1$
  - RB (Remote Bandwidth) at least 0.50 in case of RS event, thus **at least 50% of the bandwidth reserved to clients**

Conclusions & Ongoing Work

- MMHC supports **multi-hop multi-path** spontaneous connectivity exploiting off-the-shelf **heterogeneous equipment**
  - IEEE 802.11, Bluetooth, Ethernet
- Pushing for **social sharing of connectivity**
  - detection of and recover from **starvation**
  - **reward** cooperative nodes
- **Regional** scope
  - local and one-hop distant context-awareness
  - decentralized and lightweight solution

- Ongoing work
  - context-aware **peer-to-peer service** discovery and invocation
  - **security** issues: peer mutual authentication, user incentives, dynamic level of trust management

Any question?

- Prototype code and implementation insights
  - http://lia.deis.unibo.it/research/**MAC**/
  - http://lia.deis.unibo.it/research/**MACHINE**/
  - http://lia.deis.unibo.it/research/**MMHC**/
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