# Mobility-Aware Connectivity for Seamless Multimedia Delivery in the Heterogeneous Wireless Internet

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- Homogeneous Wireless Internet

- **Heterogeneous** Wireless Internet
  - several communication technologies
  - infrastructure and peer points of access

- **Mobility-Aware Connectivity (MAC)** middleware: **context-aware** dynamic **handover** procedure
  - specific characteristics of points of access: exploited technology and **infrastructure/peer**
  - client node and peer **mobility,** gathered dynamically and autonomously

# The Wireless Internet (WI)

- **Client** node
  - node **requiring** connectivity, e.g., user PDA
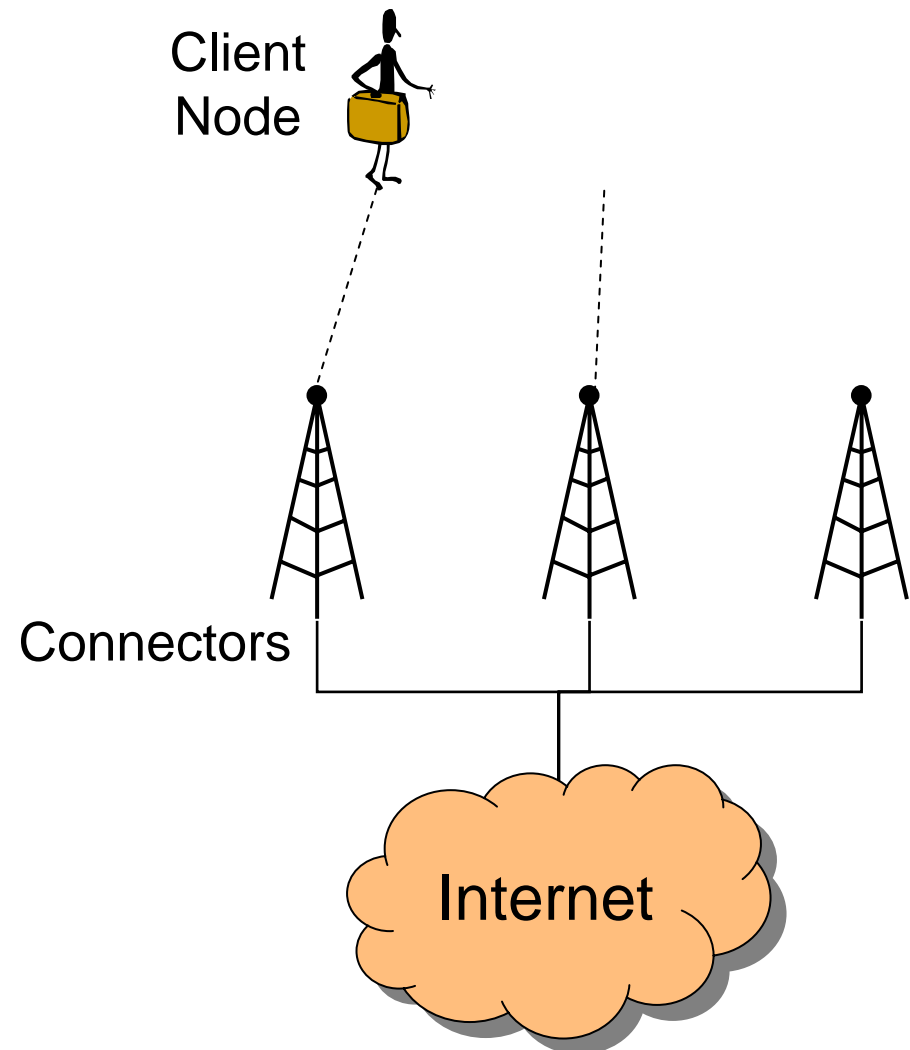
- **Connectors**
  - nodes **providing** connectivity, e.g., UMTS base station

- **Handover Procedure**
  - a client node transparently **changes** current **connector** while moving

- **Evaluation Process**
  - **context gathering**: which information are important?
  - **metric application**: which is the most suitable connector?

- **One** communication **interface** at a time
  - the client node does not change wireless interface
- **Horizontal handover**
  - origin and destination connectors based on the same wireless technology

- IEEE 802.11
  - connectors are IEEE 802.11 access points
  - metric based on Received Signal Strength Indication (RSSI) and Signal to Noise Ratio (SNR)
  - metric usually embedded in interface firmware
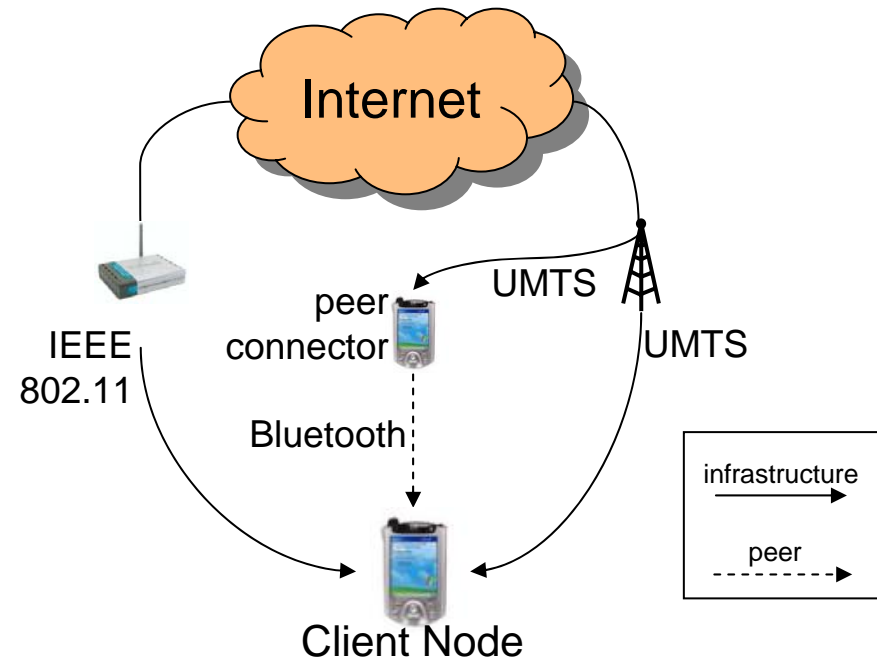
- **Heterogeneous interfaces**
  - the client node exploits **multiple wireless** interfaces, even simultaneously

- **Heterogeneous connectors**
  - can be **infrastructure** or **peer** nodes

- **Vertical** handover
  - origin and destination connectors can be based on **different wireless technologies** and **connector types**



- The **heterogeneous WI increases** client node **capabilities**:
  - heterogeneous connectors provide a **more suitable** connectivity
    - Bluetooth to limit power consumption, IEEE 802.11 to get greater bandwidth
  - peer connectors **extend connectivity** opportunities
    - UMTS link accessed via Bluetooth through a peer connector

- **Traditional** RSSI/SNR based **Evaluation Processes are not enough**

- It is required a **novel metric** considering a wide set of information
  - to **compare heterogeneous** wireless **interfaces**: bandwidth, power consumption, economic cost
    - from IEEE 802.11 to **Bluetooth** to limit **power consumption**
    - from UMTS to free **IEEE 802.11** hotspot to limit **economic cost**
  - to **consider connectors** peculiarities
    - peer connectors are **less reliable**, since may abruptly interrupt the connectivity, particularly when **client node and peer connector move**

- An **evaluation process** based on **context** knowledge, i.e., **client node** and candidate **connector characteristics**

# Mobility-Aware Connectivity

- **Mobility-Aware Connectivity** (MAC) middleware
  - evaluation metric specifically designed for heterogeneous WI scenarios

- Important context information
  - **connector characteristics**
    - wireless technology: IEEE 802.11, Bluetooth, GPRS/UMTS
    - connector type: infrastructure vs. peer
  - **client node and peer mobility**
    - client node: still vs. motion
    - peer connector: joint vs. transient

- Context information directly available on the client node
  - MAC middleware is autonomous and decentralized

- **Infrastructure**-based connectors
  - e.g., IEEE 802.11 access point and UMTS base station
  - always **reliable** and **fixed**

- **Peer**-based connectors
  - e.g., IEEE 802.11 ad-hoc and Bluetooth
  - reliable and **unreliable**
  - fixed and **mobile**
  - **joint** and **transient**
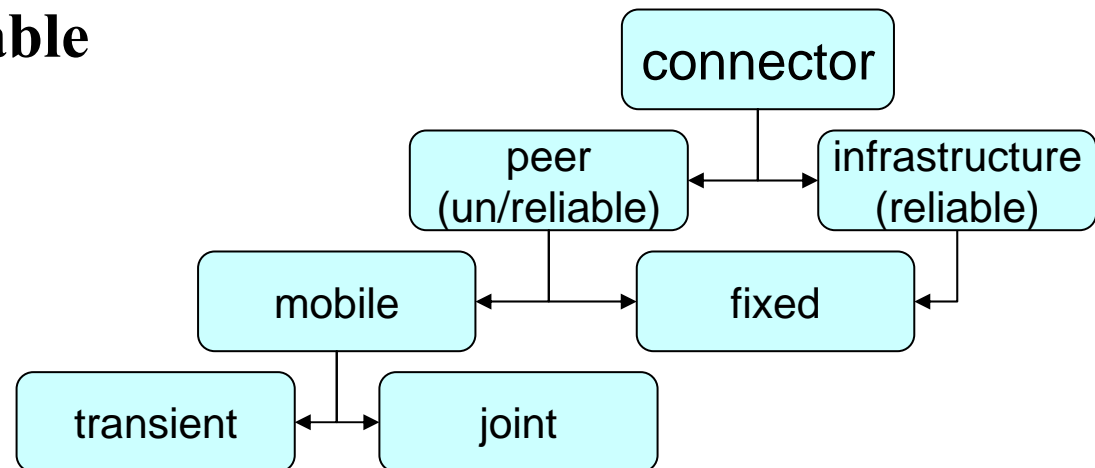
■ **Transient** peer connector

- e.g., a mobile node in the same sidewalk but with opposite direction
- **not suitable** for connectivity since has a high probability of **becoming unavailable**

■ **Joint** peer connector

- e.g., PDA connector in the same train wagon
- **suitable** for connectivity since offers **greater durability**
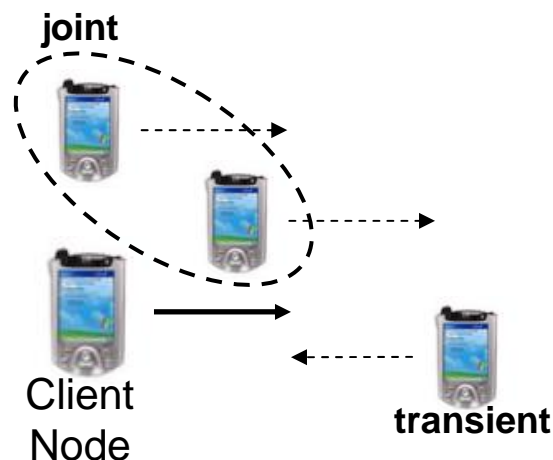
- ## **Static** context
  - – nominal bandwidth, energy consumption, coverage range, and **user requirements**

- ## **Dynamic** context
  - – **CMob** to evaluate mobile node mobility degree [0,1]
  - – **Joint** to evaluate peer connector relative mobility degree [0,1]
    - both inferred monitoring connector Received Signal Strength Indication (RSSI) variability
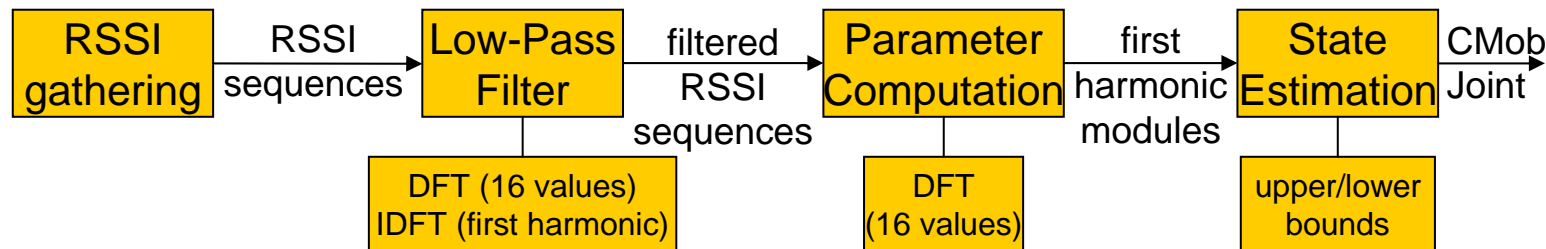
| Connector type | RSSI variability | Mobility state |
|---|---|---|
| fixed | almost <u>constant</u> | <u>still</u> client node |
| | greatly <u>variable</u> | <u>moving</u> client node |
| mobile | almost <u>constant</u> | <u>joint</u> mobile connector |
| | greatly <u>variable</u> | <u>transient</u> mobile connector |

■ **Discrete Fourier Transform (DFT)** applied twice to

   – low pass **filter RSSI fluctuations** due to signal noise

   – estimate **CMob** and **Joint**

| RSSI gathering | RSSI sequences → | Low-Pass Filter | filtered RSSI sequences → | Parameter Computation | first harmonic modules → | State Estimation | CMob Joint → |
|---|---|---|---|---|---|---|---|
| | | DFT (16 values) IDFT (first harmonic) | | DFT (16 values) | | upper/lower bounds | |

■ **Adaptive monitoring** to reduce costs

   – research or motion: **aggressive** monitoring to find a connector as soon as possible

      ■ frequent monitoring of nearby connectors

   – connected and still: **lazy** monitoring to understand if relevant events happen

      ■ frequent monitoring of the current connector and occasional monitoring of other connectors
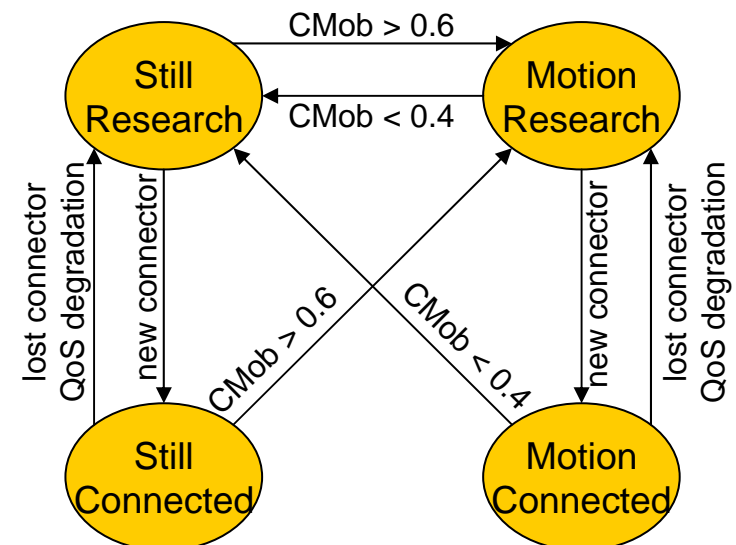
- **Current MAC metric**:
  - **enduring connections** as the primary objective in heterogeneous WI scenarios
    - minimize number of handover procedures
  - other requirements as secondary goals
    - minimize power consumption and maximize available bandwidth
- *ConnectorValue = EnduranceValue + QualityValue*
  - **EnduranceValue**: expected connector durability
  - **QualityValue**: expected quality in terms of bandwidth and energy consumption

| Connectort type | EnduranceValue | QualityValue |
|:---:|:---:|:---:|
| **Fixed** | *CMob · Range* | *(1 - CMob) · (α·Bandwidth + β·Energy)* |
| **Mobile** | *(1 – Joint) · Range* | *Joint · (α·Bandwidth + β·Energy)* |

- Examples:
  - **mobile** client node (CMob ≈ 1) or **transient** peer connector (Joint ≈ 0)
    - not easy to provide enduring connections ➜ primarily consider connector **Range** to **maximize connection durability**
  - **still** client node (CMob ≈ 0) or **joint** peer connector (Joint ≈ 1)
    - enduring connections easily provided ➜ consider additional requirements, e.g., **bandwidth** and power **consumption** in relation to **user requirements α and β**

- **Home-Office-Home** mobility model
  - client node **still** in **well served locations**
    - limited/medium range **infrastructure connectors** available, e.g., IEEE 802.11 access points or Bluetooth fixed peer connectors
  - client node **mobile** in **poorly served locations**
    - **large range infrastructure** connectors more suitable to increase connection durability, e.g., UMTS base stations
    - when available even **joint peer connector** may be suitable, e.g., Bluetooth joint peer connectors

| Client node state | Wireless interface | Connector type |
|---|---|---|
| **Still** | Bluetooth ≈ 802.11 >> UMTS | fixed connector >> joint peer |
| **Motion** | 802.11 ≈ UMTS >> Bluetooth | infrastructure ≈ joint peer >> transient peer |

(≈ equivalent, > better, >> much better)

# Conclusions & Ongoing Work

- **Mobility-Aware Connectivity (MAC)** middleware adaptively considers opportunities heterogeneous WI scenarios provide

- MAC proposes a **novel Evaluation Process** considering
  - different **wireless** technologies, e.g., Bluetooth and IEEE 802.11
  - several **connector types**, e.g., infrastructure and peer
  - a novel more expressive **context information**, i.e., client node and peer **mobility**

- Future work:
  - CMob and Joint estimation based on **Bluetooth**
  - **double-layered metric**
    - the bottom layer considering O.S. requirements (power consumption)
    - the top layer considering application requirements (bandwidth)

- Acknowledgements:
  - Work supported by the MIUR PRIN **MOMA** and the CNR Strategic **IS-MANET** Projects

- Web references for software and additional documents:
  - **http://lia.deis.unibo.it/Research/MAC/**
  - http://lia.deis.unibo.it/Staff/CarloGiannelli/

■ **Evaluation Process**

  – **context gathering**: which information are important?

  – **metric application**: which is the most suitable connector?

■ Continuity Management

  – trigger: when actually performing an handover?

  – switcher: how keeping connections alive?

Evaluation Process      Continuity Management

| context gathering | metric application | trigger | switcher |
|---|---|---|---|
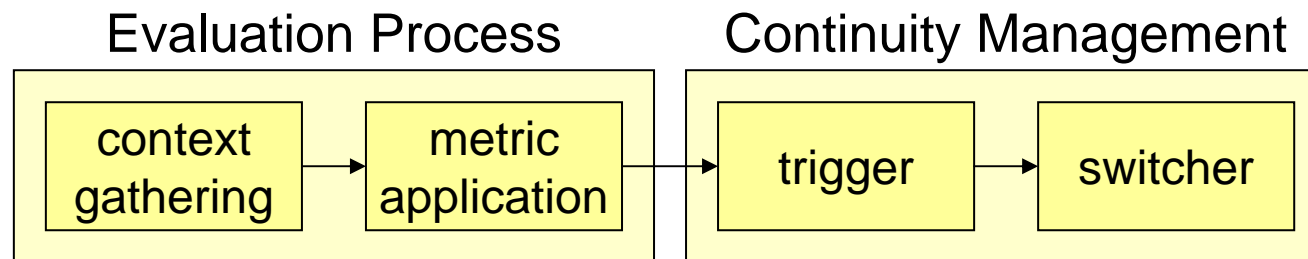
- **Wrapper**
  - **homogeneous** access to wireless interfaces
- Network Interface **Provider**
  - **aggregated** access to wireless interfaces
  - **plug-in** wireless interfaces registration