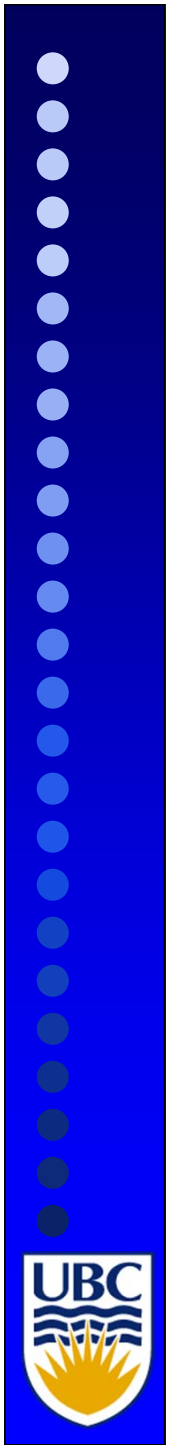

Advances in Wireless Networking Research - Recent Results and New Initiatives

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17 December, 2010

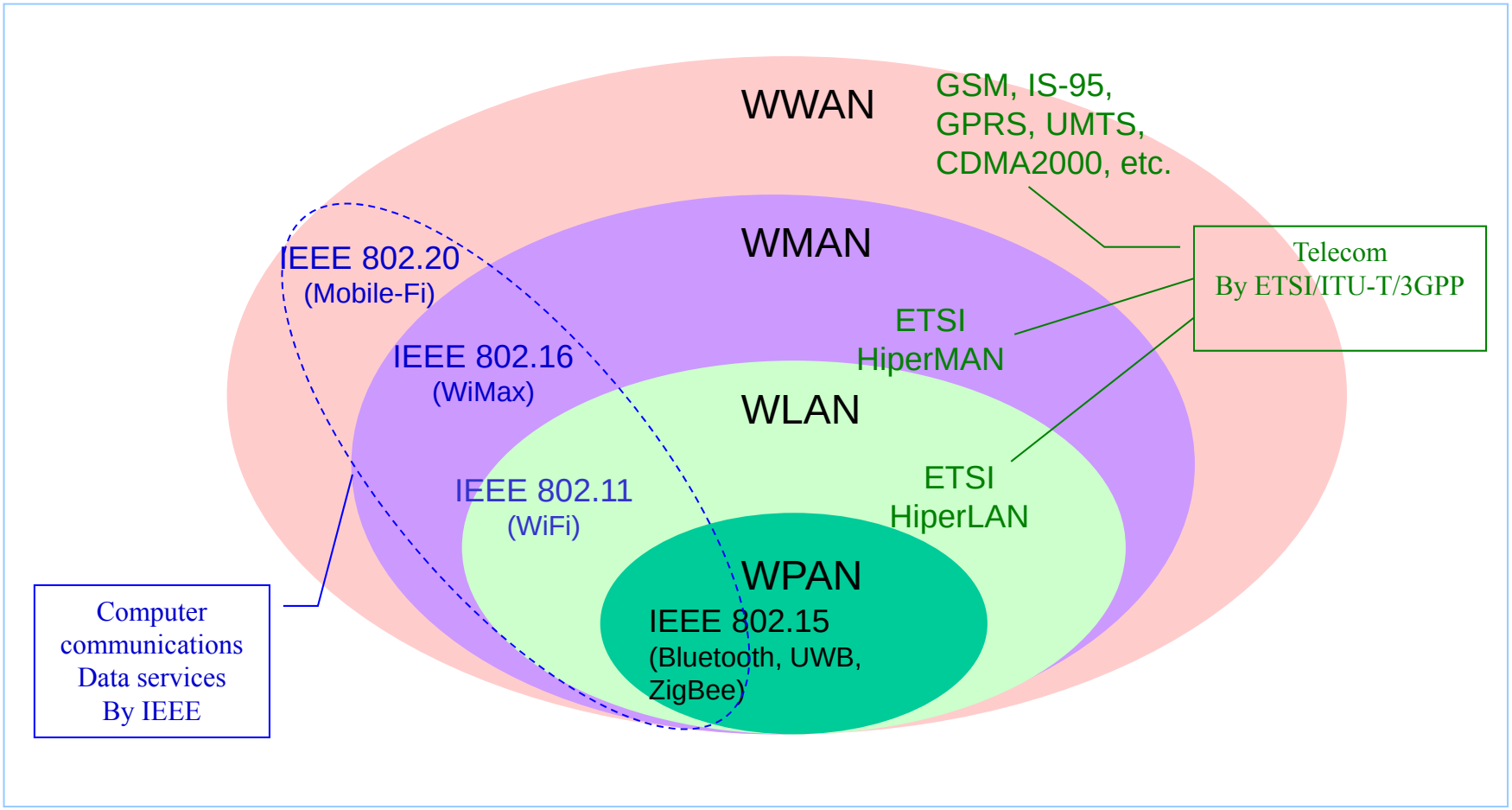
Outline of the Presentation

- Current trends and future challenges in wireless networking
- Recent results on:
  - Interworking of heterogeneous wireless networks
    - Network selection for service invocation
    - Seamless vertical handoff operation
    - Optimization of vertical handoff decision
  - Vehicular networking for intelligent transportation
    - Robust ad hoc data dissemination for safety applications
    - Connectivity-aware minimum-delay geographic routing
    - Vertical handoff decisions in heterogeneous vehicular networks
- New initiatives
  - More vehicular networking
  - Next generation broadband wireless
  - Application specific wireless sensor networks

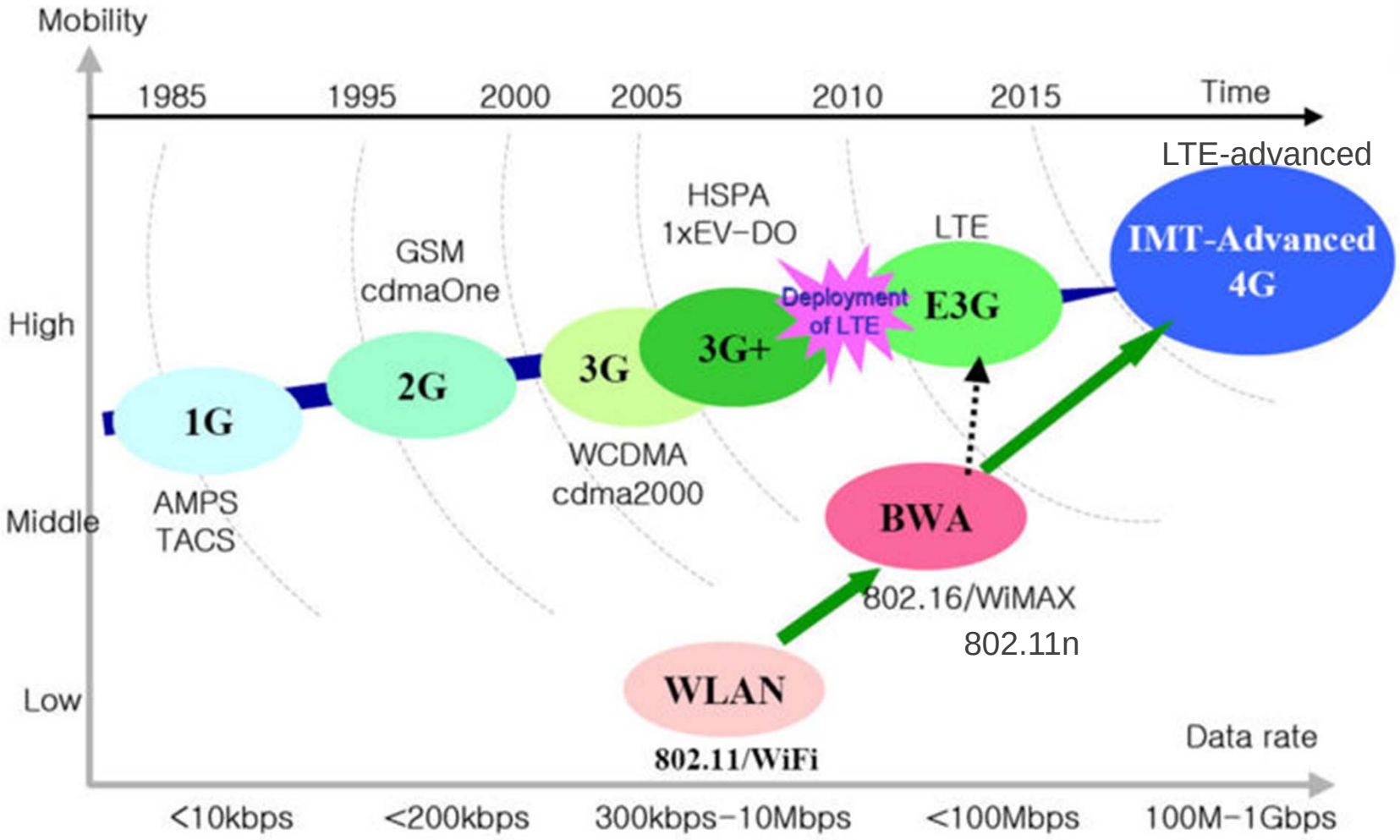
The Wireless Landscape

PAN: Personal Area Network
LAN: Local Area Network

MAN: Metropolitan Area Network
WAN: Wide Area Network



Roadmap of Cellular Technologies

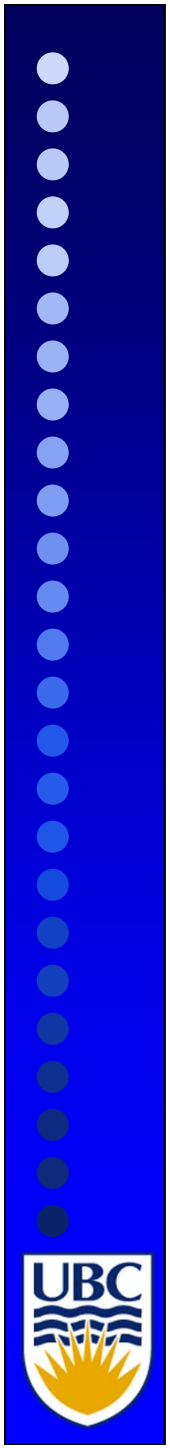


Current Trends in Wireless Networking

- Support of applications and services will continue to migrate towards IP-based broadband networks
- Portable devices will be equipped to support multiple wireless standards
  - Multiple wireless interfaces
  - Software defined radios
- Users have multiple alternatives for network access and need various aids for decision making
- License-free wireless will play an important role in interconnecting electronic devices in homes and work places
  - Broadband wireless for multimedia entertainment devices
  - Lower rate longer range wireless for monitoring and control
  - Practical civilian deployment of wireless ad hoc and sensor networks

Future Challenges in Wireless Networking

- Higher data rate, better coverage, longer battery life, lower cost
- Cognitive radio network → cognitive wireless network
- Wireless access becoming a commodity / utility
  - Applications, applications, applications
- User-friendly technology-agnostic wireless access
  - Convergence of access networks and application services over core IP multimedia system result in break down of service silos
  - Need to manage subscriber access over multiple heterogeneous access networks for ubiquitous service access with uniform quality
- Application specific wireless networking
  - Vehicle-infrastructure integration, vehicule ad hoc networking
  - Wireless body area network, wireless healthcare / e-medicine
  - Wireless home networking interconnecting multimedia entertainment devices, security devices, home control systems
  - Sustainable, green wireless networking

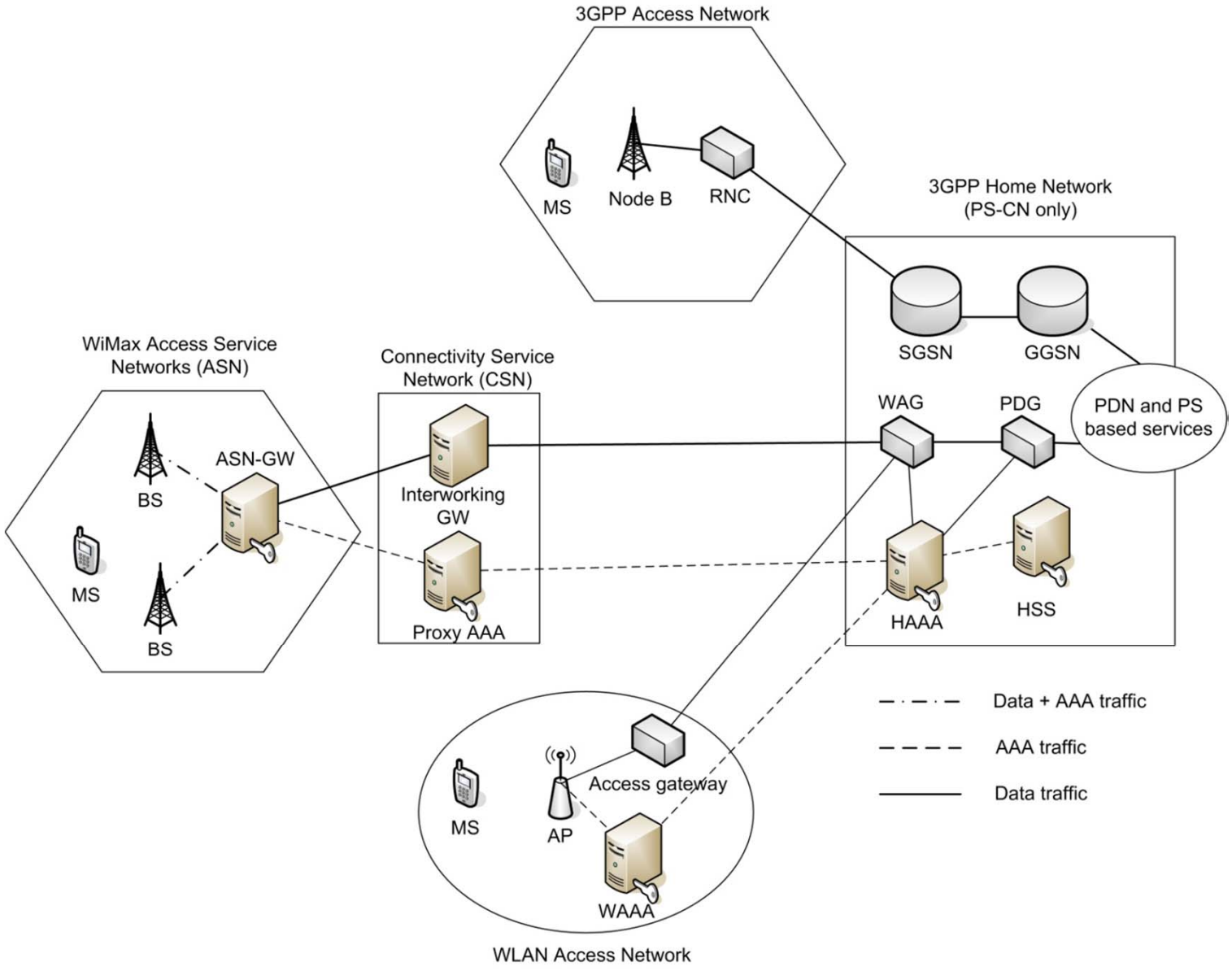


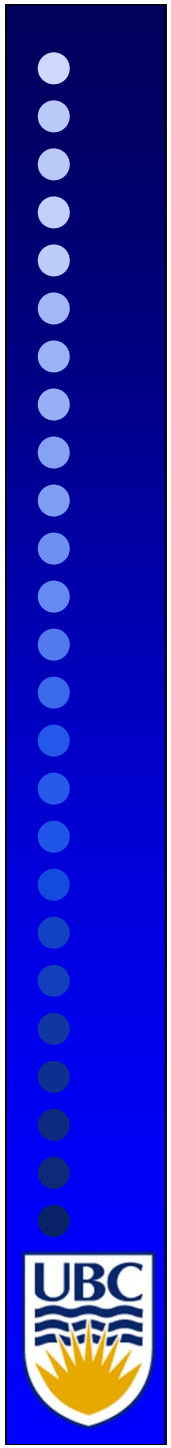
Interworking Heterogeneous Wireless Networks

Contributions from: Farooq Bari
Li Ma
Ji Zhang

Collaborations with: Henry Chan
Tejinder Randhawa
Fei Richard Yu

Heterogeneous Network Architecture





Network Selection for Service Delivery across Heterogeneous Wireless Networks

Significance of Network Selection

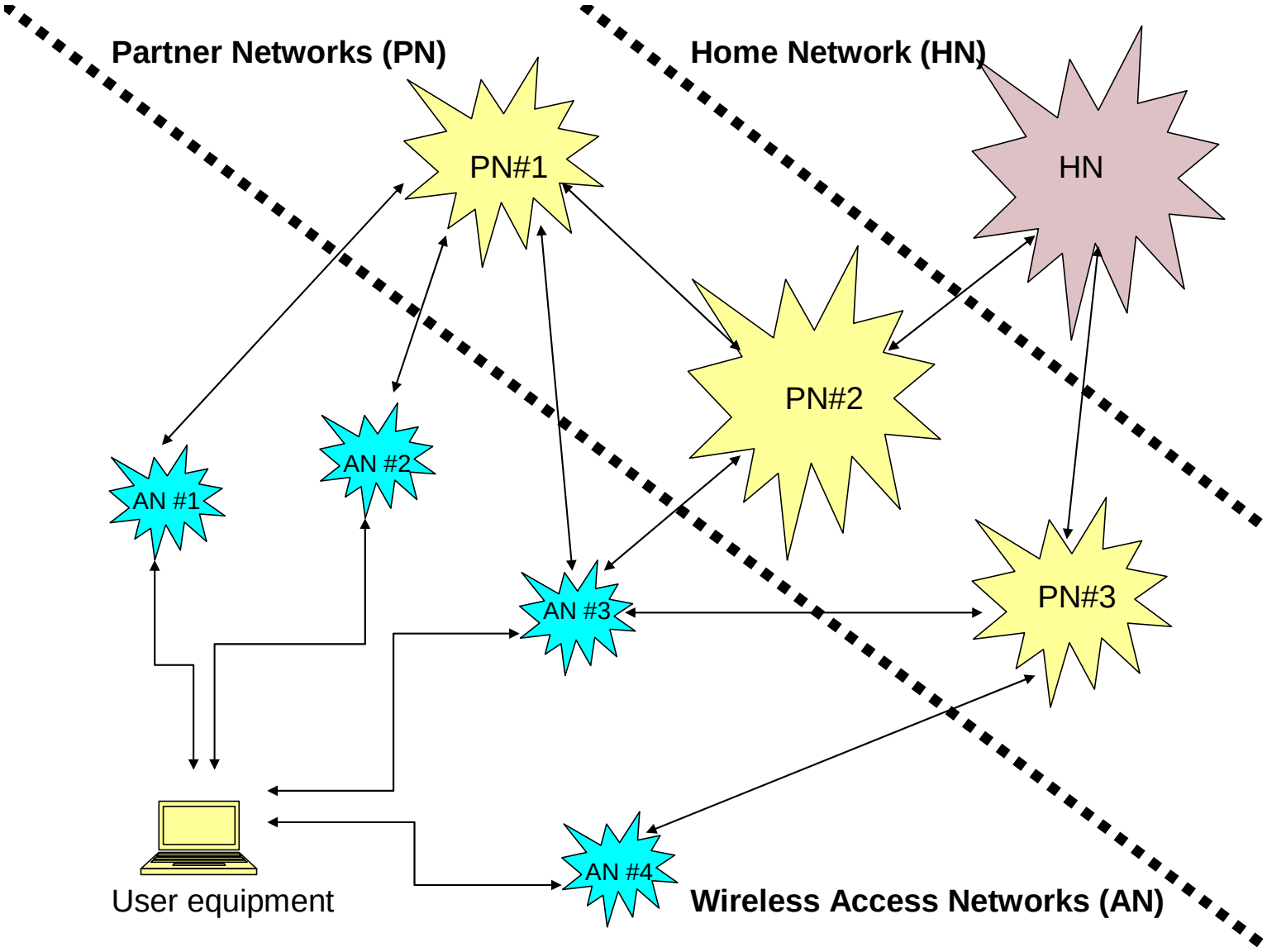
- Reliable network selection mechanisms are essential for working of next generation networks supporting heterogeneous wireless technologies
- Necessary action before service invocation when devices equipped with multiple radio interfaces
- Network selection impacts customer satisfaction and service experience
- An appropriately selected network can decrease possible inter technology handoffs later on
- Network selection issues are currently under discussion in major industry / standards forums such as IEEE 802, IETF, 3GPP, 3GPP2

Architectural Options

- **Terminal based approach** - the terminal itself discovers available networks, collects data from candidate networks, analyzes the data and makes the selection

- **Network assisted approach** - the terminal uses the network to assist in the selection process by relying on the network to find roaming partners, collect data from candidate networks and analyze the data to come up with recommendations; user or terminal makes decision on the selection based on the recommendations

Proposed Architecture – Network Assisted Approach



Proposed Architecture

The following functions are added to each network domain:

Network Information Node (NIN)

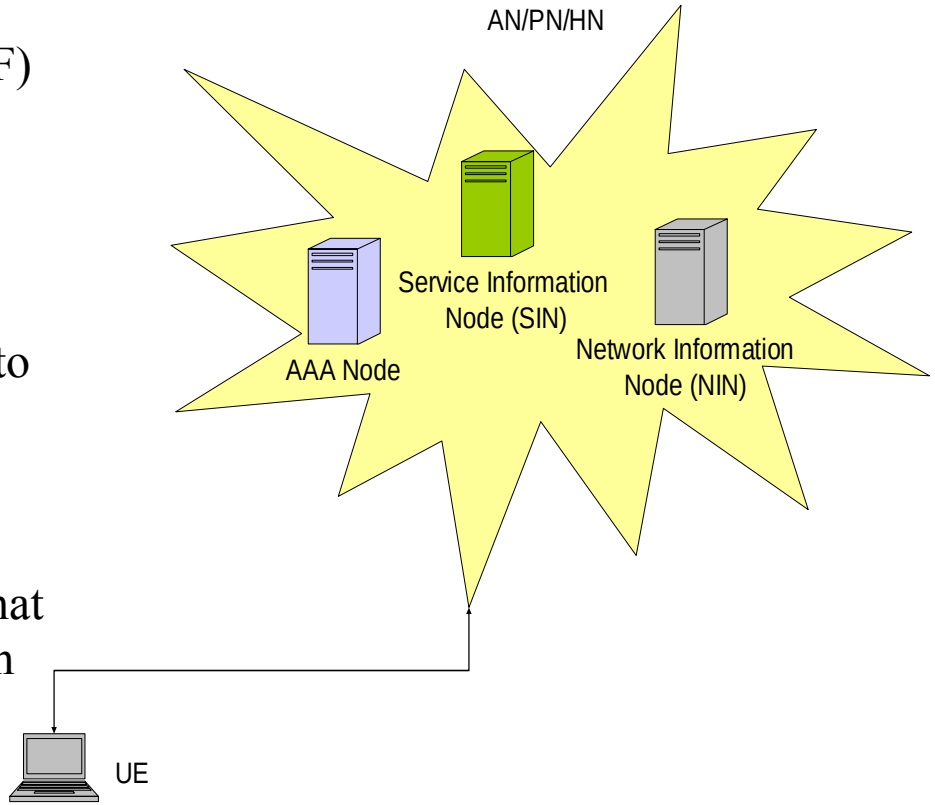
- Information collector function (ICF) – Monitors and collects information on network conditions
- Information provider function (IPF) – Stores and exchanges this information across autonomous domains

Service Information Node (SIN)

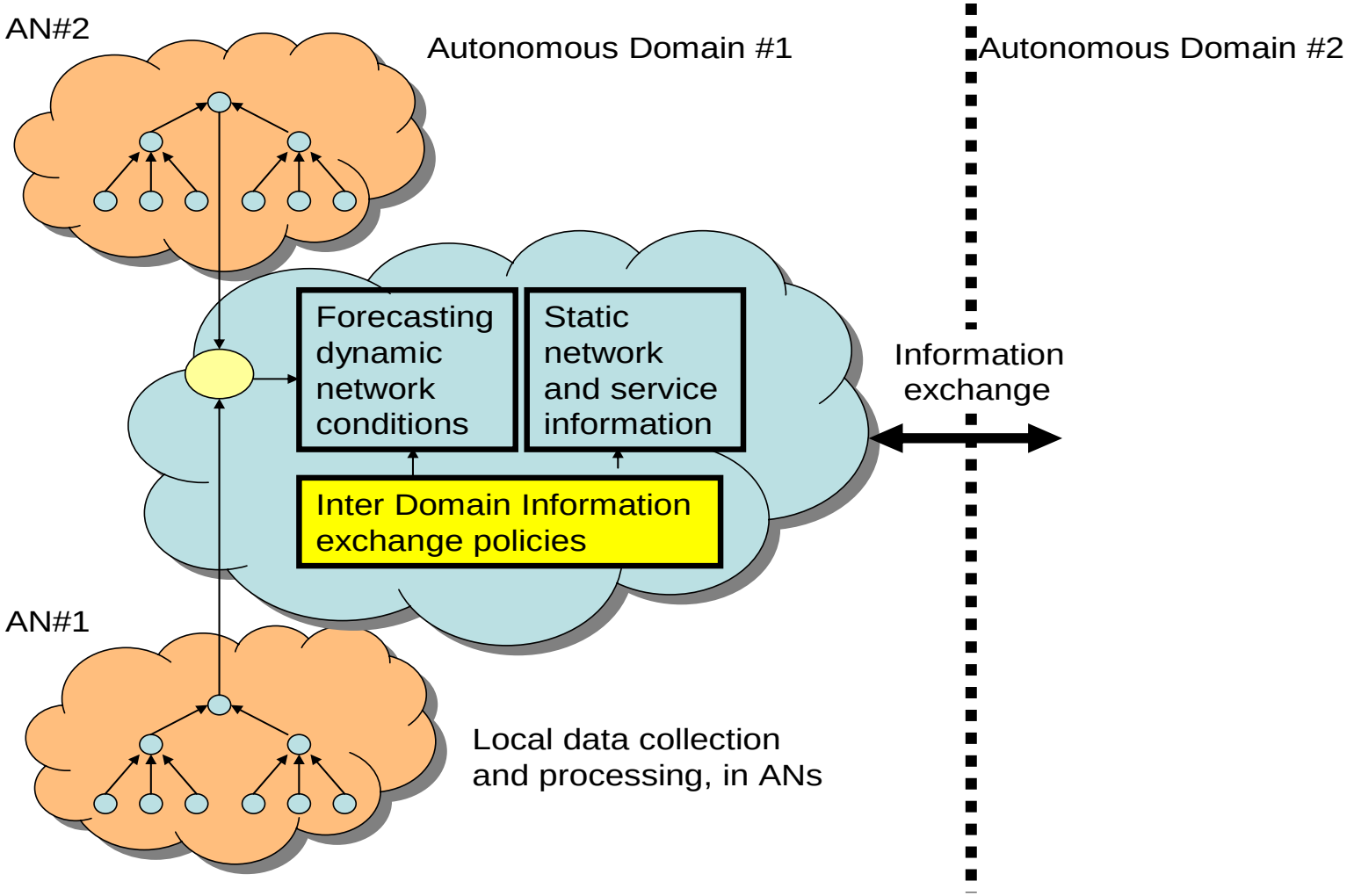
- Announces the services available to users via different networks at users' current location

AAA Node

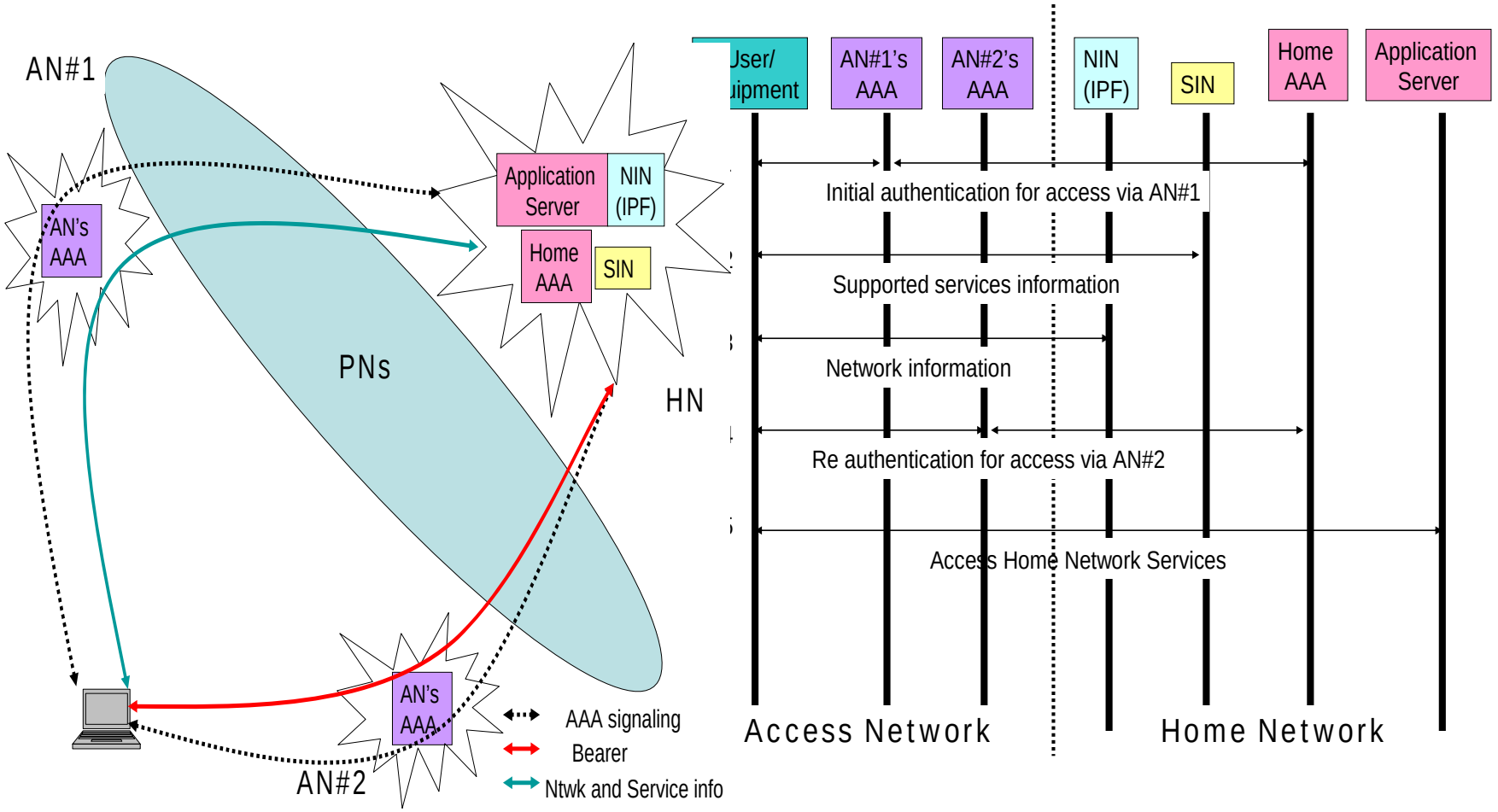
- Deals with multimode terminals that have to exchange information such as user identity, HN identity with backend servers while working across different network types.



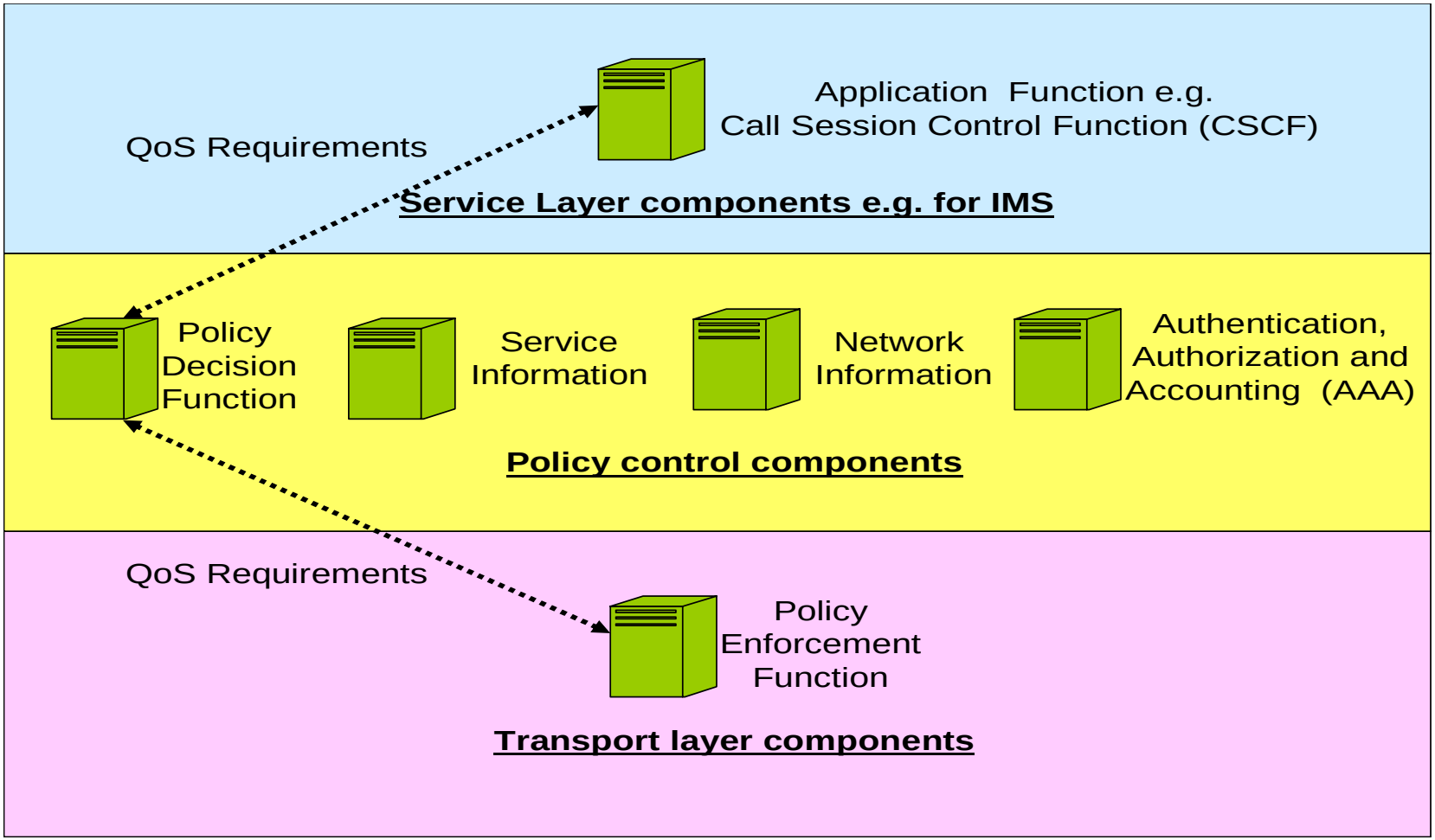
Information Collection



Network Selection using Proposed Architecture



Policy Based Network Selection

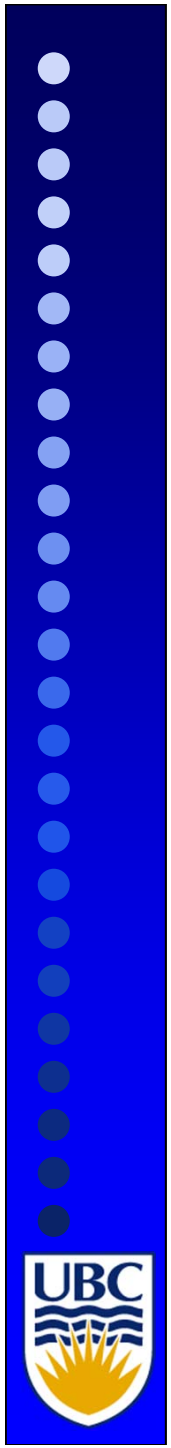


Attributes Impacting Network Selection

1. AAA Mechanism
2. Access Technology
3. Services Available
4. Geographic Location
5. Coverage Area
6. Cost per Byte
7. Total Bandwidth
8. Allowed Bandwidth
9. Utilization
10. Packet delay
11. Packet Jitter
12. Packet Loss

Multi Attribute Decision Making (MADM)

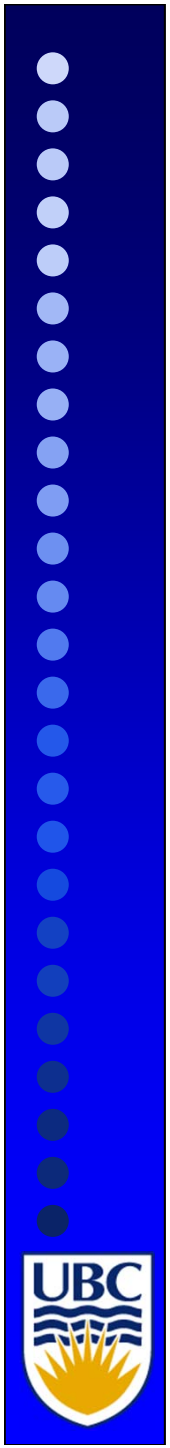
- Making preference decisions over the available alternatives while taking into consideration multiple criteria impacting the decision
- Provide solution in discrete decision spaces where decision alternatives are predetermined
- Attribute values can be deterministic, fuzzy or stochastic
- MADM involves the following steps:
  1. Identify all alternatives and attributes impacting the decision process.
  2. Assign relative importance in the decision making process to each of the attributes
  3. Use a MADM algorithm to get a ranking / preference for the alternatives
- Many MADM algorithms exist, such as TOPSIS, ELECTRE, GRA
  - Need improvements and adaptations to apply towards network selection problem



Vertical Handoff between WLAN and Cellular Networks Using SCTP

Issues with Vertical Handoff between Internet Domains

- Conventional method employs Mobile IP
  - Requires home agent and foreign agents
  - Additional delay due to triangular routing
  - Additional overhead due to packet tunneling
- Mobility support based on SIP is attractive for multimedia traffic, but may have long latency
- Stream Control Transmission Protocol (SCTP), a next generation Internet transport protocol, is well suited to mobility support over the Internet



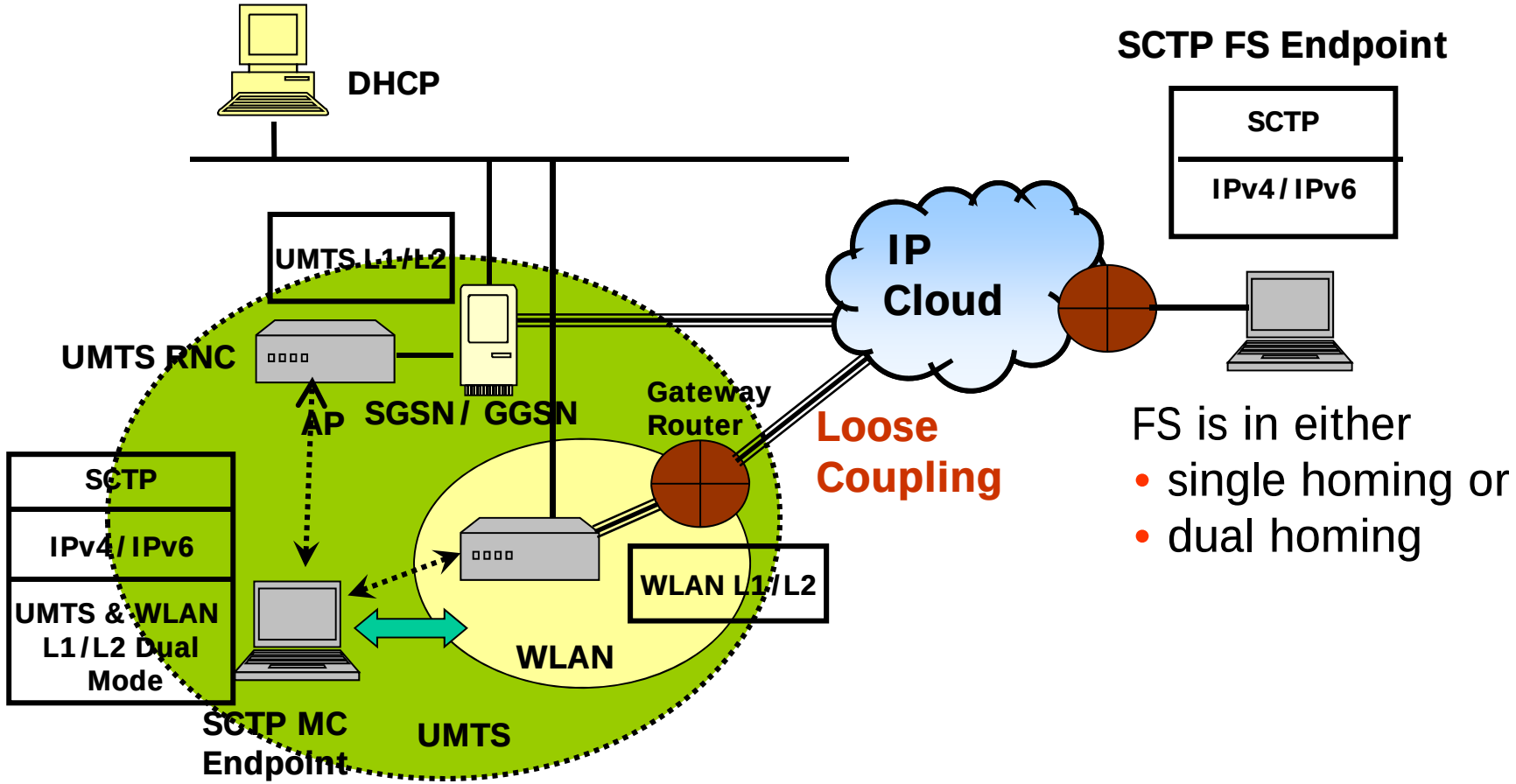
SCTP Overview

- Stream Control Transmission Protocol (SCTP) originally designed to support SS7 over IP
- Accepted among IETF standards for transport layer protocols (together with TCP and UDP)
- Supports multi-homing and multi-streaming
- Improved error recovery using SACK
- Support real-time transfer of time-limited messages and unordered data
- At least 26 kernel and user space implementations available in FreeBSD, Solaris, Linux, Windows, etc.
- Simulation tools: ns-2 and OPNET
- Proposed extensions:
  - Dynamic Address Reconfiguration (DAR)
  - Partial Reliability (PR)

Mobile SCTP (mSCTP)

- Enabled by multi-homing and DAR features of SCTP
- Assume both fixed server (FS) and mobile client (MC) support SCTP with DAR extension
- MC is assumed to be equipped with both cellular and WLAN interfaces and is dual-homing
- MC employs multi-homing, acquires new IP address in new location via either DHCP or IPv6 Stateless Address Auto-configuration
- Downward handoff triggered by appropriate decision process
- Upward handoff usually forced by loss of WLAN coverage

Architecture of UMTS/WLAN Vertical Handoff Using SCTP



FS is in either
- single homing or
- dual homing

Issues with Forced Handoff

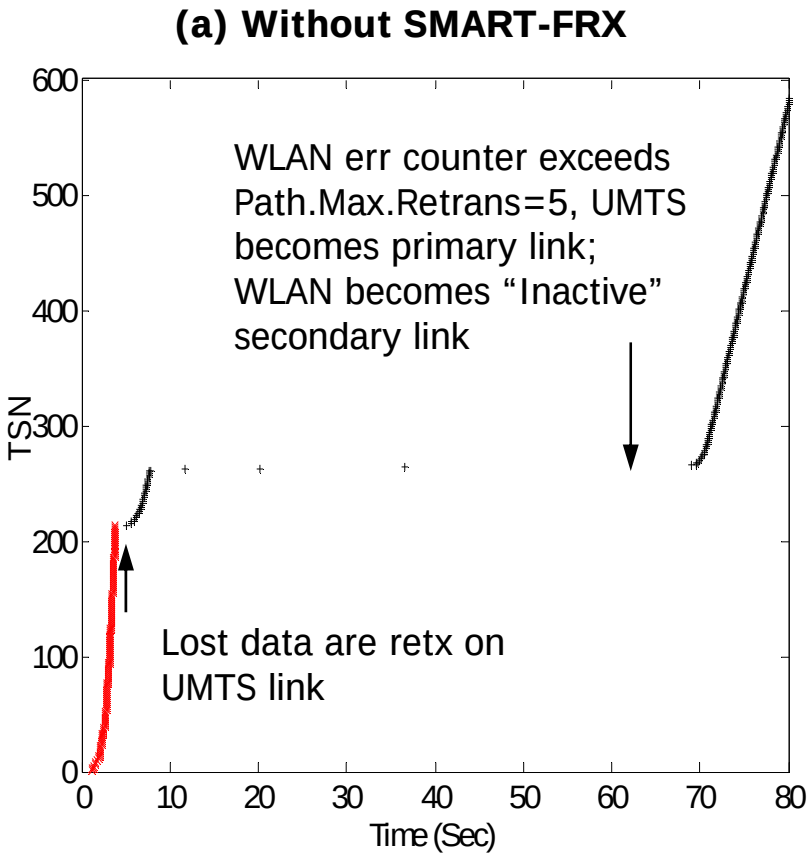
- Forced handoff occurs when wireless coverage is lost and MC is forced to switch over to an alternate medium
- In cellular / WLAN vertical handoffs, a forced handoff most likely occurs when the MC leaves the coverage area of a WLAN hot spot
- Handoff management agent could be developed to monitor imminent loss of coverage and facilitate smooth transition to the alternate medium
- In the absence of a management agent, SCTP loss recovery mechanism can be employed to automatically force a switch over into the alternate medium as the primary link
- Performance issues exist with SCTP loss recovery due to excessive delay in switching over to secondary link

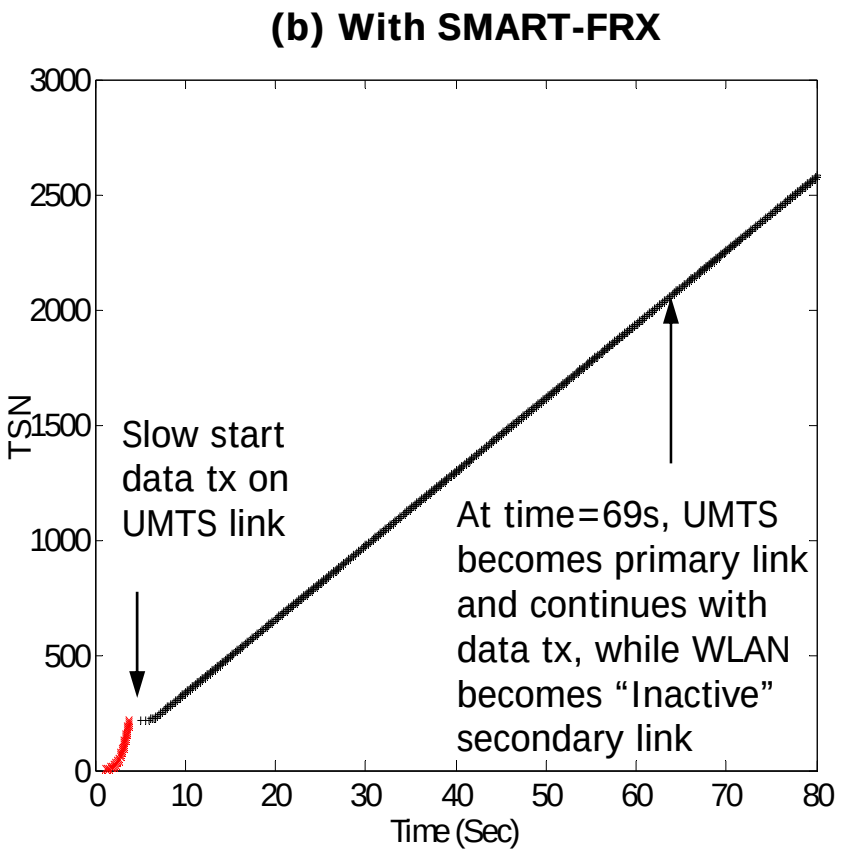
SMART-FRX (Sending-buffer Multicast with Fast Retransmission)

- **SMART** (Sending-buffer Multicast-Aided Retransmission) – multicast buffered and new data on both cellular and WLAN links to deal with handoff losses over the WLAN link during the forced vertical handoff period
- **FRX** (Fast Retransmission) – when random transmission losses occur over the wireless link, retransmissions are sent over the same link, i.e., to the same destination IP address (instead of the alternate IP address as specified in SCTP)

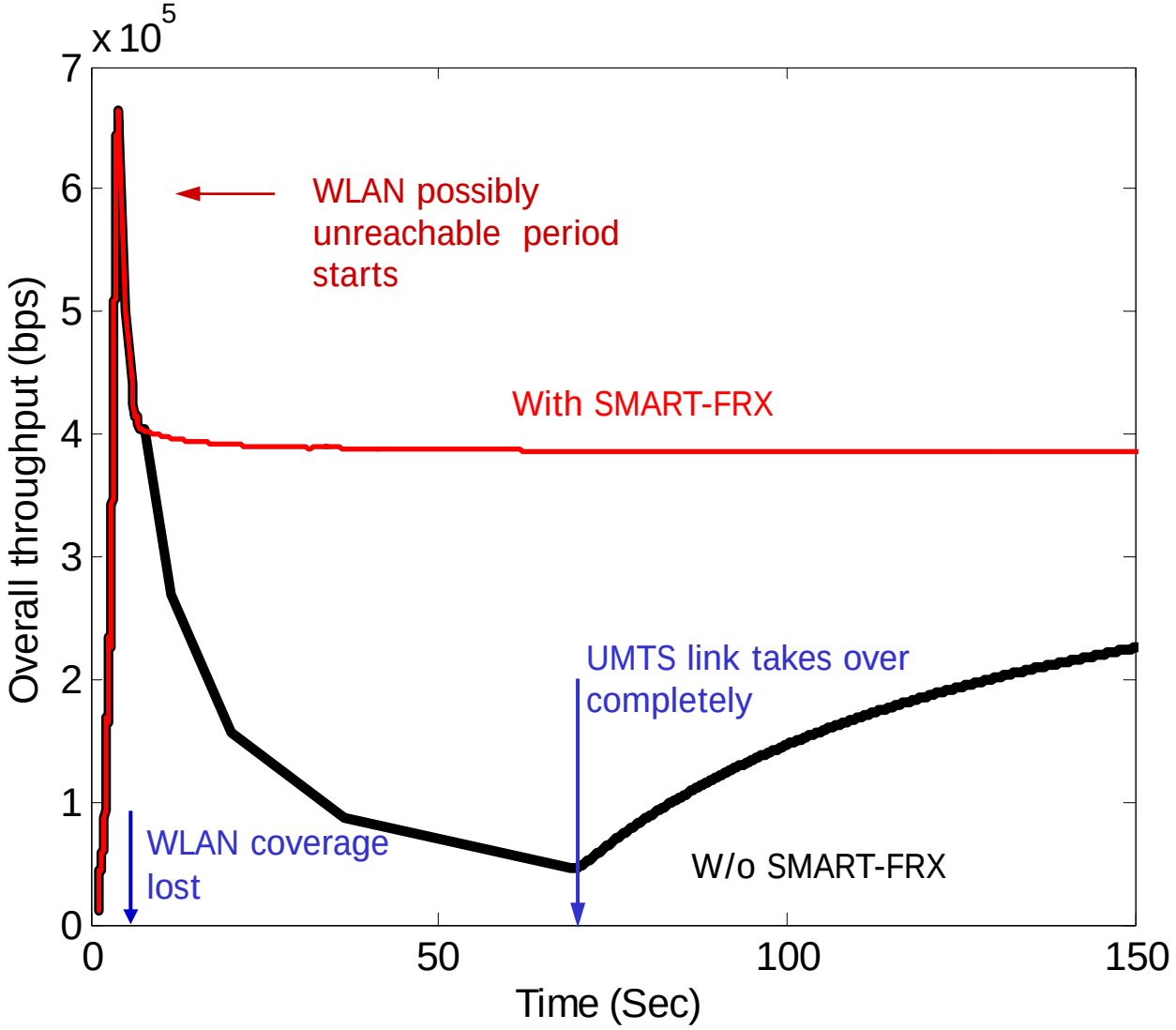
SMART-FRX Data Tx Behavior

(WLAN link final error counter = 6)

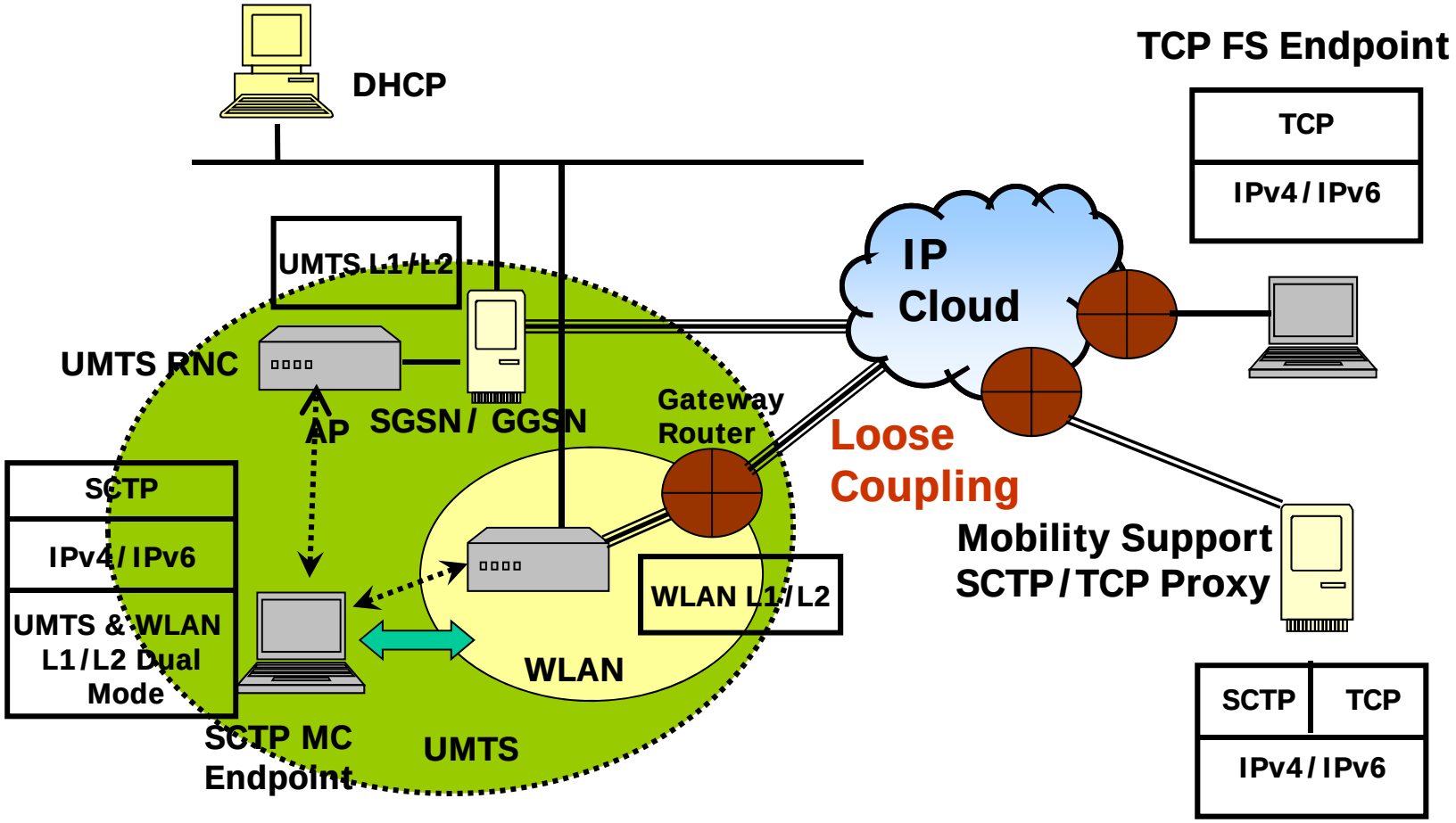


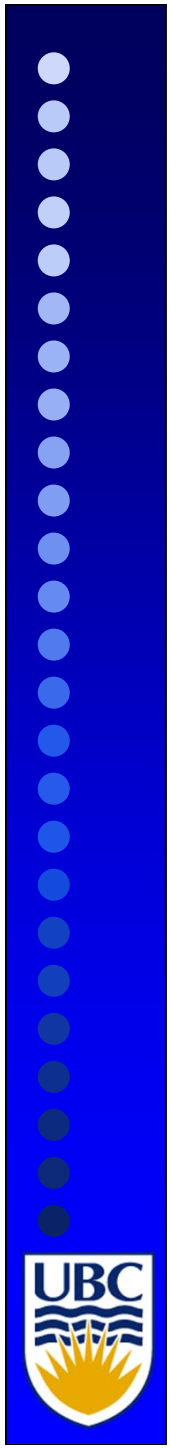


SMART-FRX Throughput



Proxy Service Supporting Vertical Handoff Using SCTP





Optimization of 3G/WLAN Vertical Handoff Decisions

Handoff Management in NGN

- Conventional (intra-system) handoff:
  - Horizontal handoff
  - Compulsory to maintain connection
  - Not direction dependent
- Mobile devices in NGN will be equipped with multiple radio interfaces
- Inter-system or inter-technology handoffs:
  - Vertical handoff
  - Directional dependent
  - Downward handoff, e.g., cellular → WLAN
    - optional to maximize the satisfaction on service
    - to handoff or not to handoff …
  - Upward handoff, e.g., WLAN → cellular
    - compulsory, to keep the call connectivity

Downward Handoff Decision

- Goal: provide ABC service, maximize overall user satisfaction utility
- Handoff gain
  - Service enhanced by accessing broadband wireless network (BWN), e.g., WLAN
  - Proportional to connection period
- Handoff cost
  - Service degradation during vertical handoff, such as packet lost, signalling cost
  - One-time costs:
    - cost for downward handoff
    - cost for upward handoff when MT moves out of BWN coverage before session ends
- Handoff only if the gain offsets the cost
- Decision depends on
  - Mobility: the sojourn period of MT in BWN
  - Traffic: connection lifetime

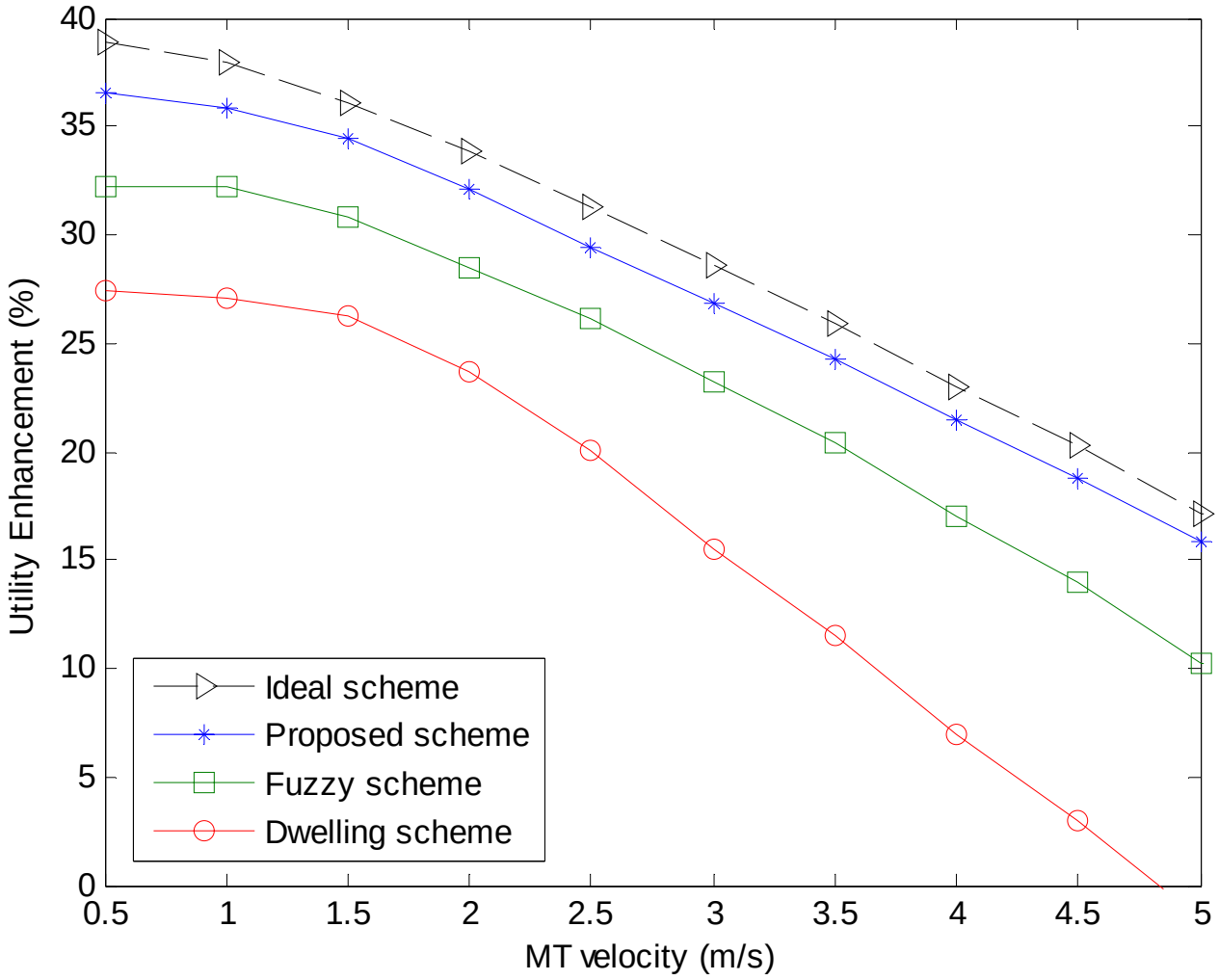
Existing Downward Handoff Mechanisms

- Few recent work takes into account of
  - Received signal strength (RSS)
  - Speed of mobile
- Examples
  - "Fuzzy scheme" (Majlesi and Khalaj): handoff occurs when the RSS of the BWN exceeds a threshold determined by fuzzy logic based on the mobile's speed and the BWN traffic load
  - "Dwelling scheme" (Wang et. al.): handoff is made after the mobile has been in the BWN coverage area for a period of time

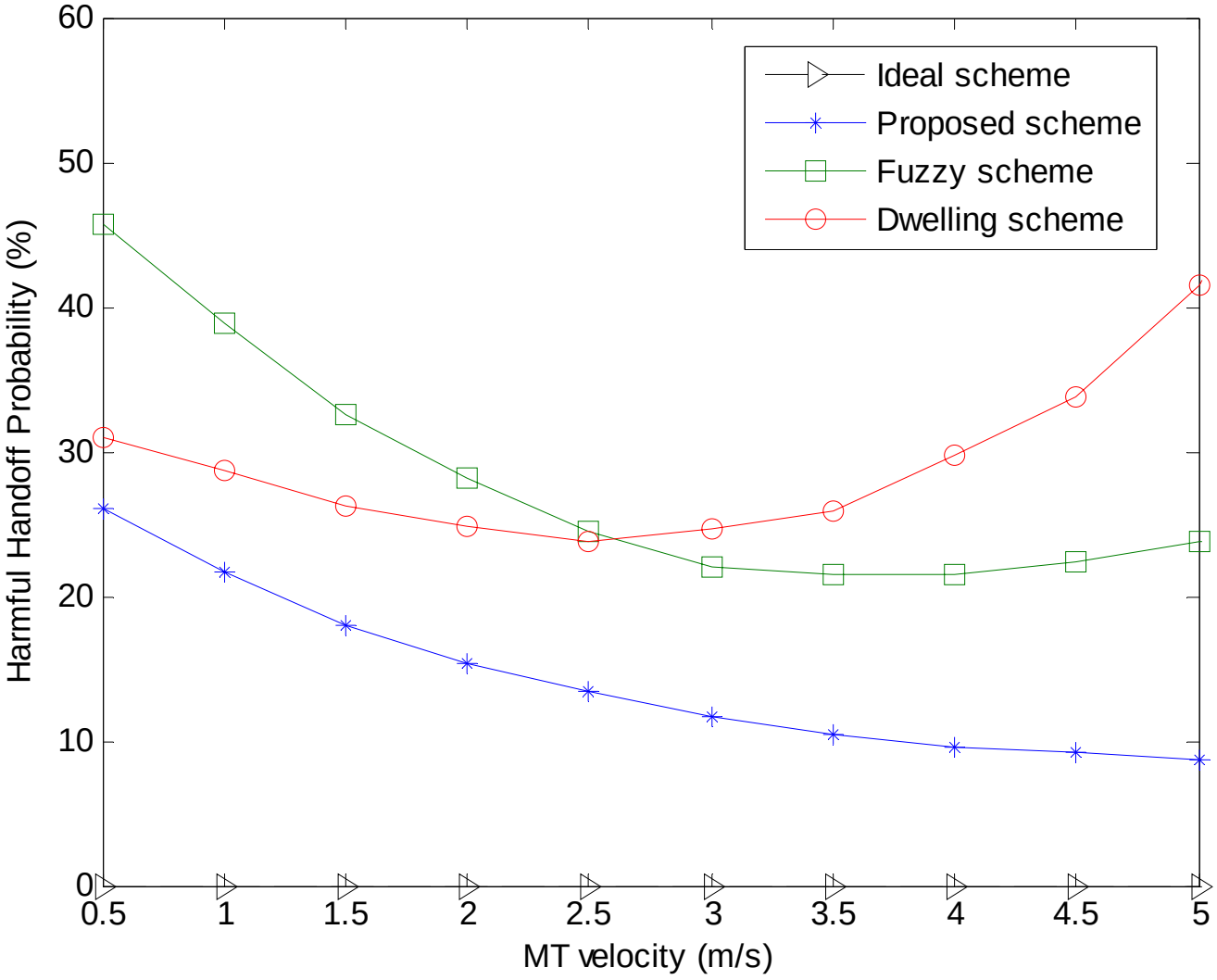
Optimization of Handoff Decision

- Utilize discounted Markov Decision Process to optimize downward handoff decisions at regular time intervals
- Assume mobiles equipped with location tracking capability and report positions and RSS of BWNs to a location service server (LSS), which determines possibly irregular coverage boundaries of BWNs at the vicinity of a mobile
- Mobile's movement modeled by a Gauss-Markov mobility model differentiated according to mobile's situation, e.g., open area or roadway
- Mobile's connection length assumed exponentially distributed
- Expected sojourn time in BWN estimated when entering BWN coverage area based on mobility and traffic model
- Execute downward handoff if expected utility for the connection is increased by the handoff

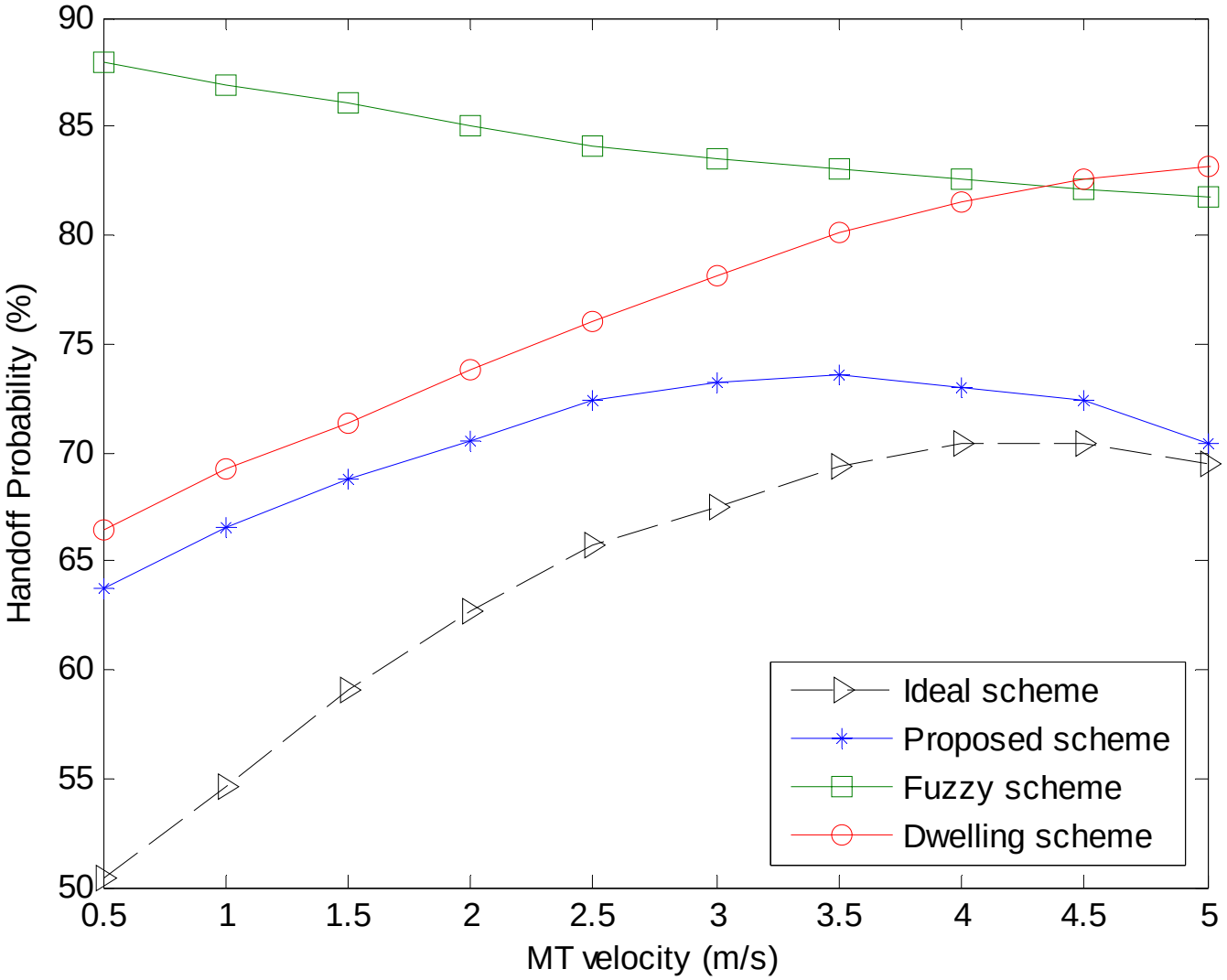
Comparison of Utility Enhancements

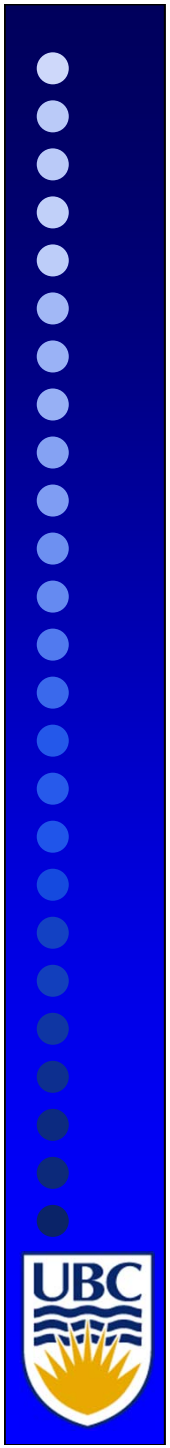


Harmful Handoff Probability



Handoff Probability



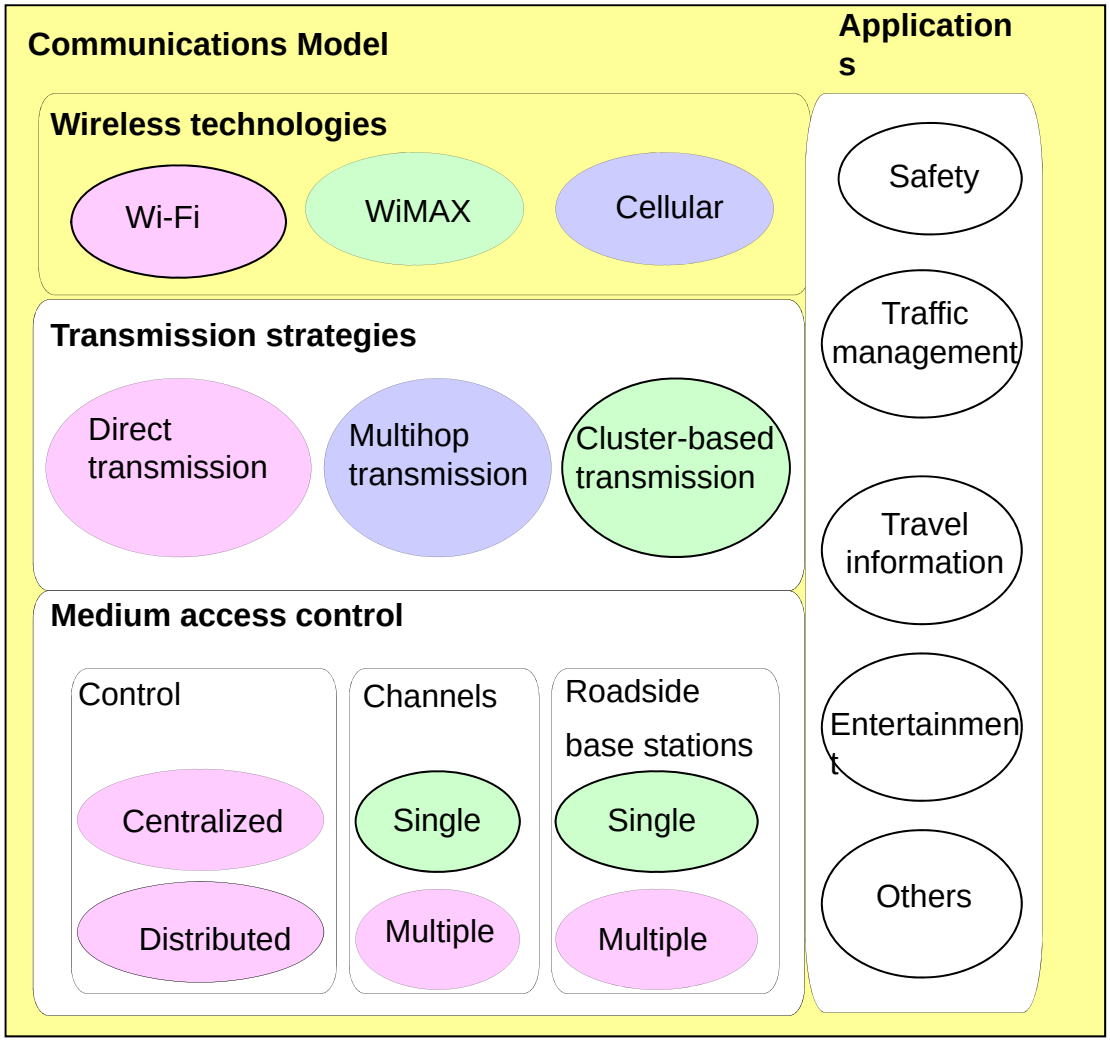


Advanced Vehicular Communications Platform for Intelligent Transportation

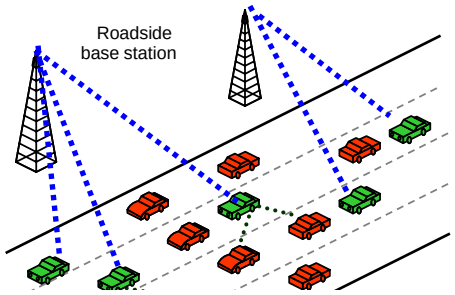
Auto21 Project F303-FVT: Vehicular Telematics over WiFi and WiMax Multihop Networks

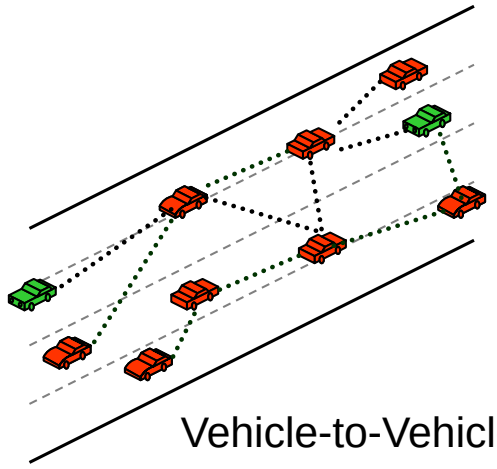
Contributions from:
Kaveh Shafiee
Seyedali Hosseininezhad

Advanced Heterogeneous Vehicular Communications Platform



Vehicle-to-Roadside

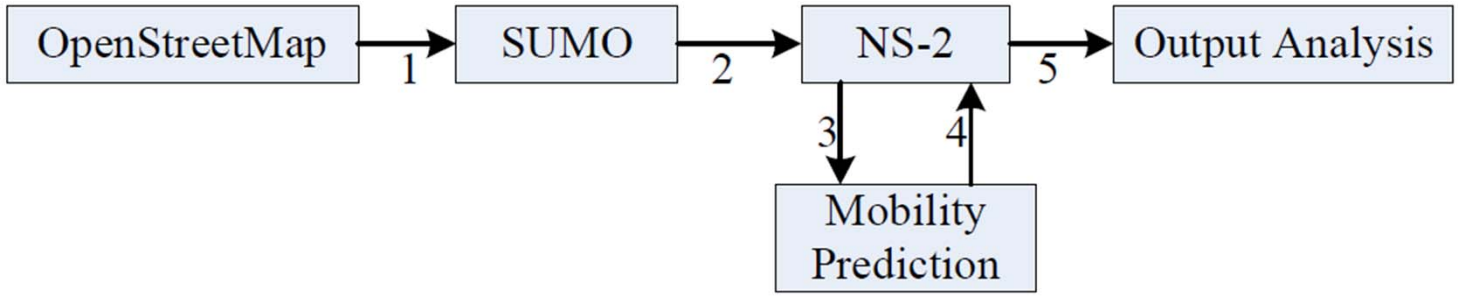




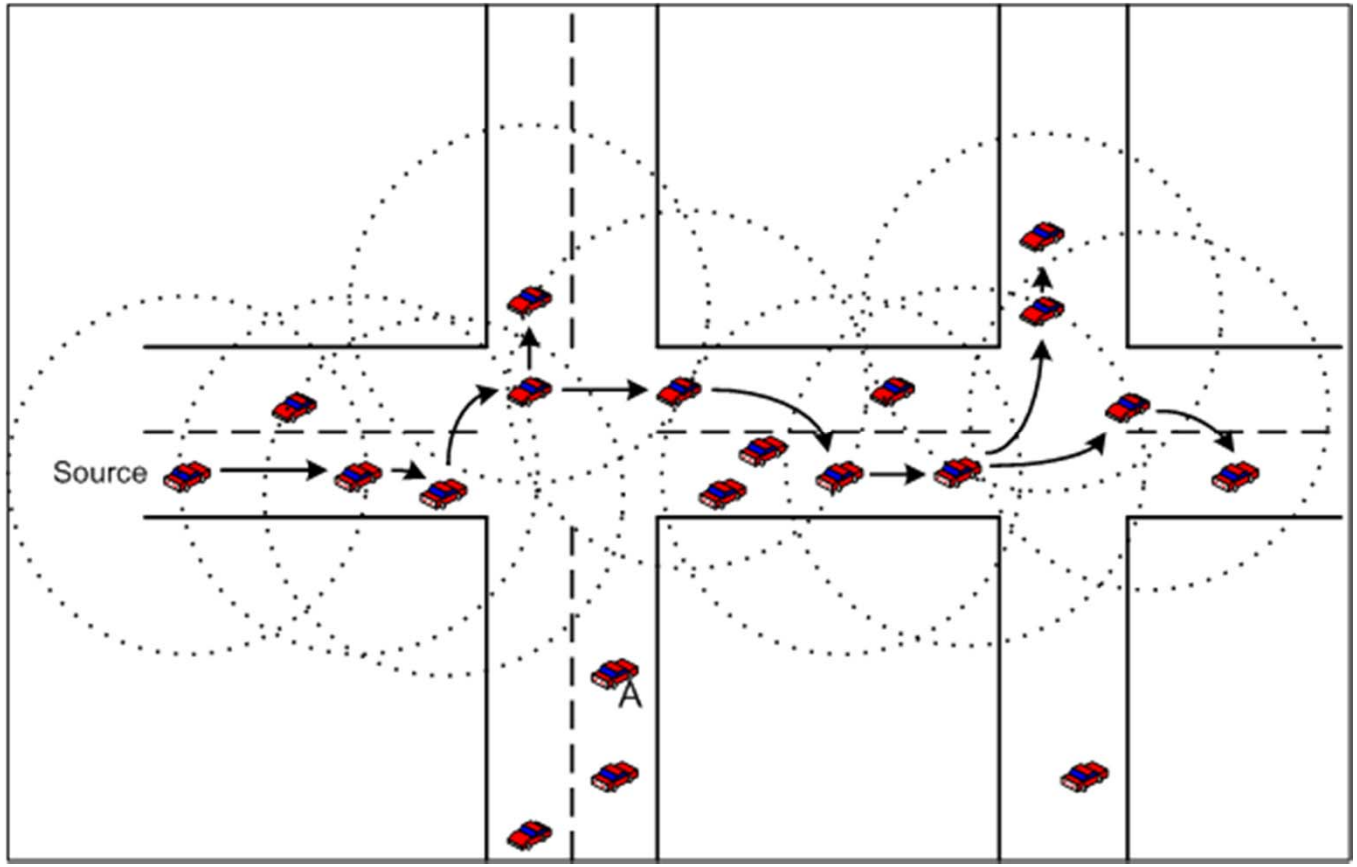
Vehicle-to-Vehicle

System Evaluation Methodology

- Computer simulations most commonly used for system performance evaluations
- Wireless networks commonly evaluated using simulators such as ns2
- Vehicular networking in ITS characterized by movements that follow rules of traffic and confined to streets and highways
- Need proper vehicular traffic simulator

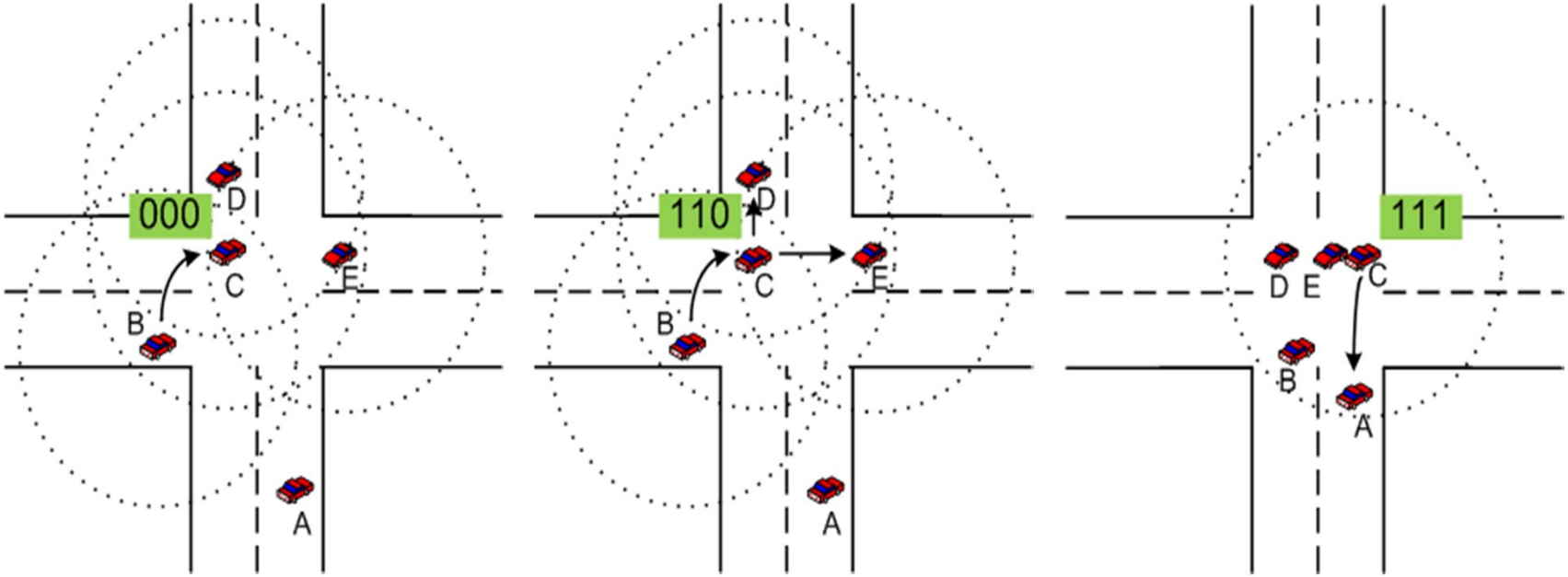


Robust Ad Hoc Data Dissemination for Safety Applications



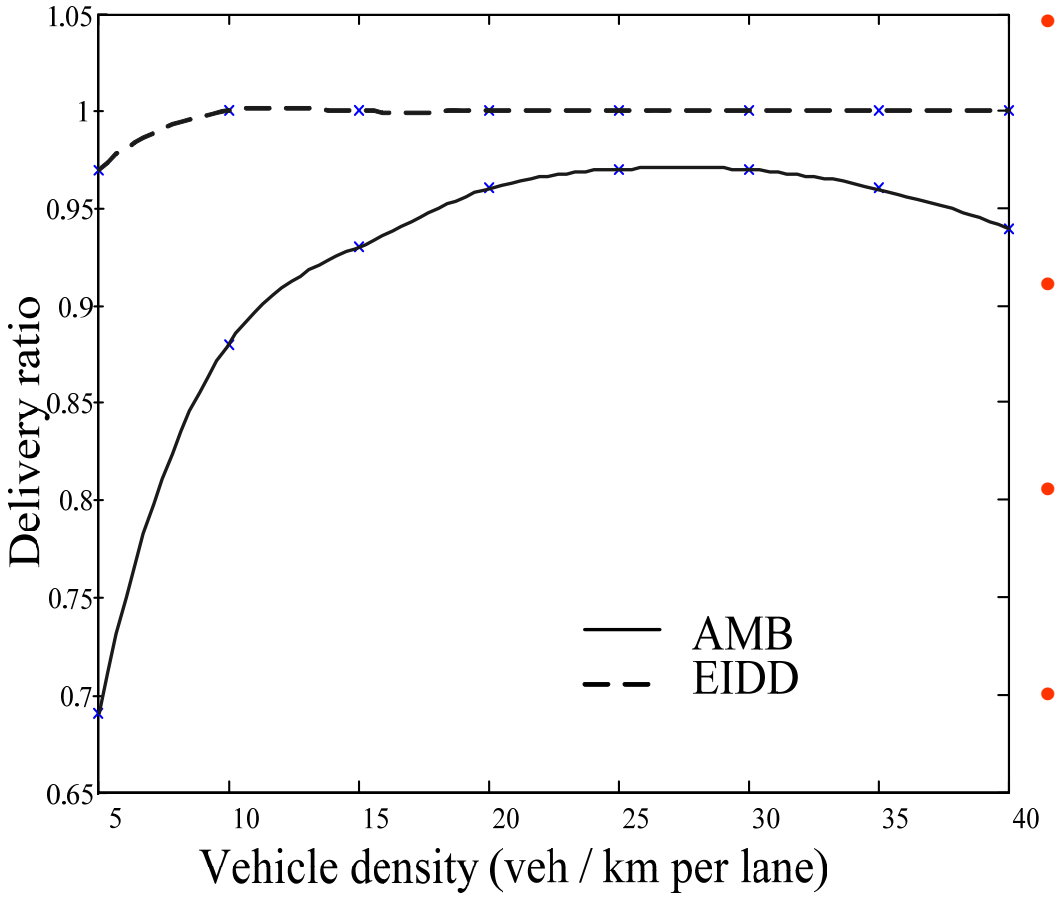
Challenge: overcoming ad hoc delivery failure around intersections

Enhanced Intersection-mode Data Dissemination (EIDD)



- Add some bits to the header of an emergency message as it enters a junction, each bit corresponding to one outgoing direction at the junction
- A bit is set to one when the message is propagated to the corresponding outgoing direction at the junction
- The message is kept at the junction until all the header bits are 1

Simulation Results

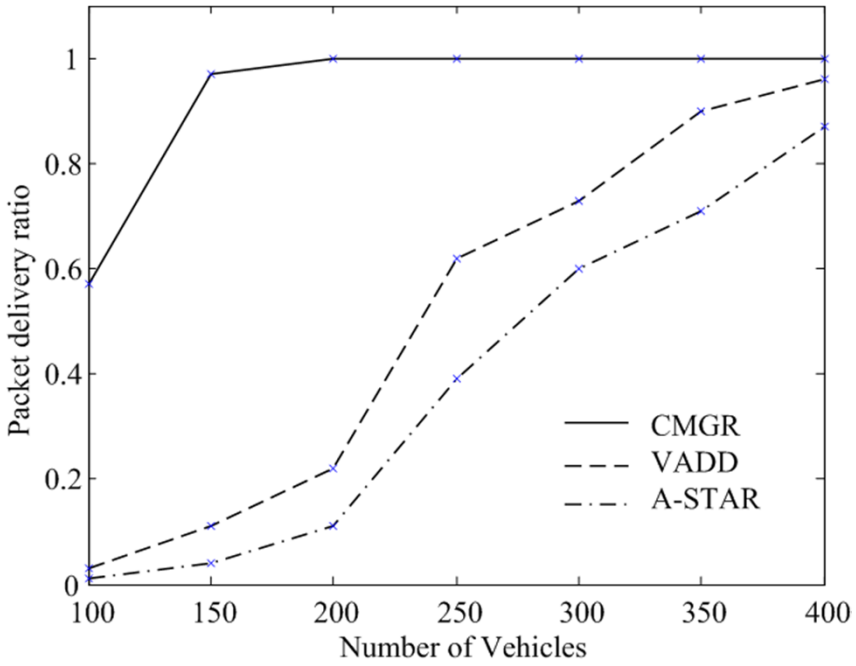


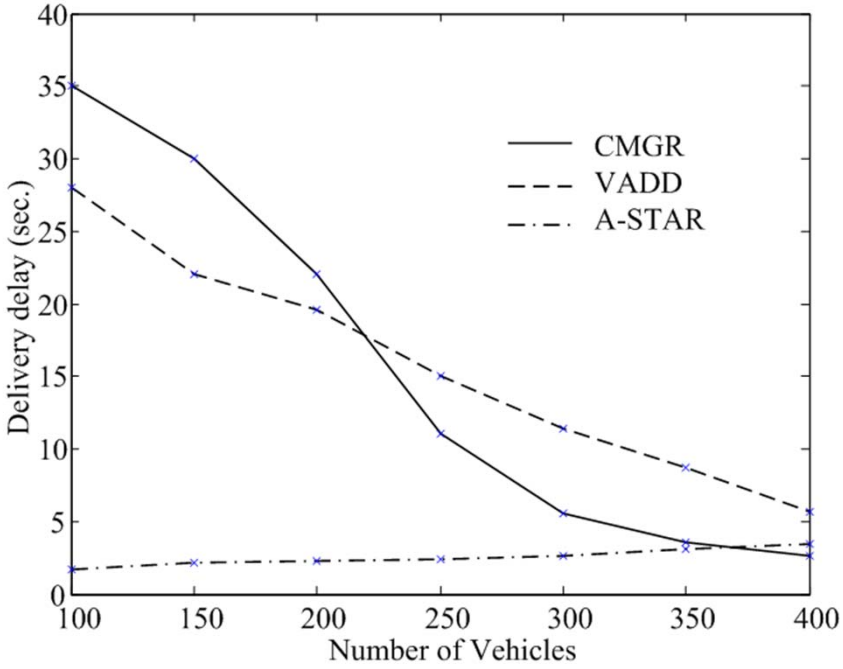
- Define Delivery Ratio as the percentage of the vehicles that get notified in the simulation time
- Comparison with Ad-hoc Multi-hop Broadcast (AMB)
- Delivery Ratio of EIDD is close to 100% for almost all vehicle densities
- EIDD shows the highest improvement in lower vehicle densities

Connectivity-aware Minimum-delay Geographic Routing (CMGR)

- Vehicular ad hoc networks (VANETs) are specialized mobile ad hoc networks (MANETs)
  - Highly variable vehicle densities and potential high speeds
  - Vehicles follow traffic rules and confined to roads
- Proposed CMGR adapt to changing vehicular densities by
  - Favouring routes with higher connectivity to maximize the chance of reception when traffic is sparse
  - Avoiding congested routes when traffic is dense
- Enhanced by a vehicular tracking mechanism to deal with the situation where the source vehicle has turned a corner
  - *Keep velocity vector in intersection until route reply comes back*

Simulation Results with One Gateway





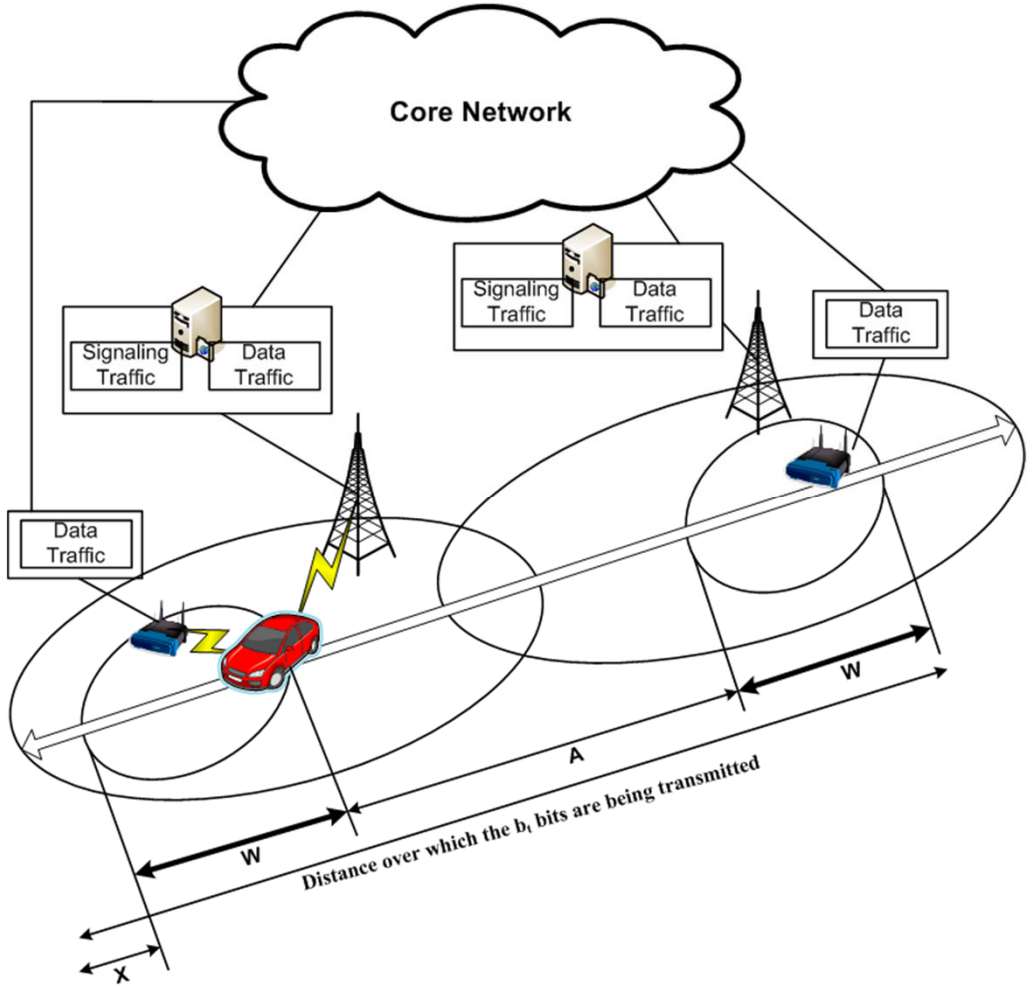
Comparisons with:

- Anchor-based street and traffic aware routing (A-STAR)
- Vehicle-assisted data delivery (VADD)

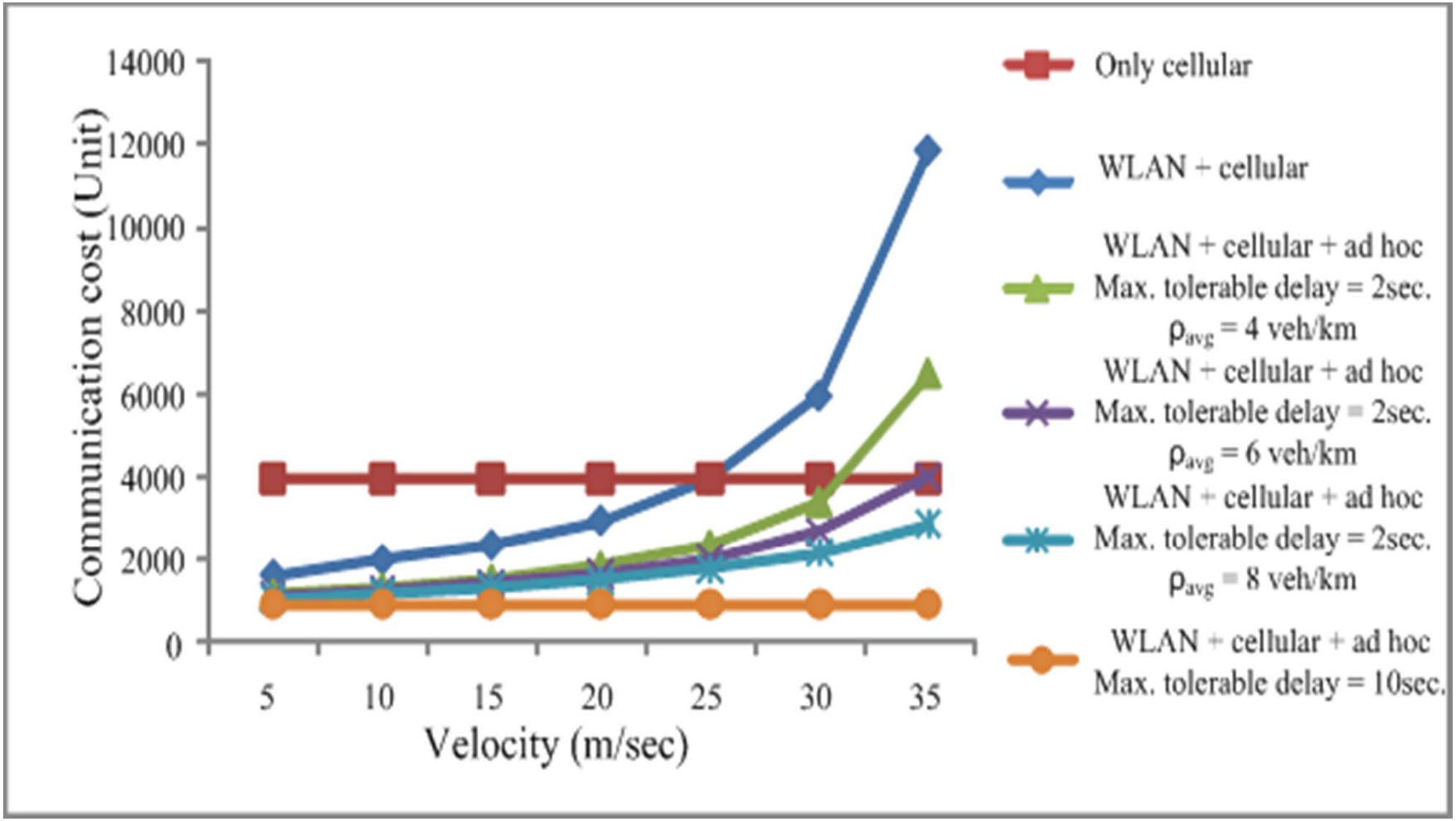
Vertical Handoff Decisions in Heterogeneous Vehicular Networks

- Which network to select for data delivery?
- Objective: minimize total cost by considering the signaling costs of vertical handoffs
- Distributed VHO decision algorithms for 3 scenarios

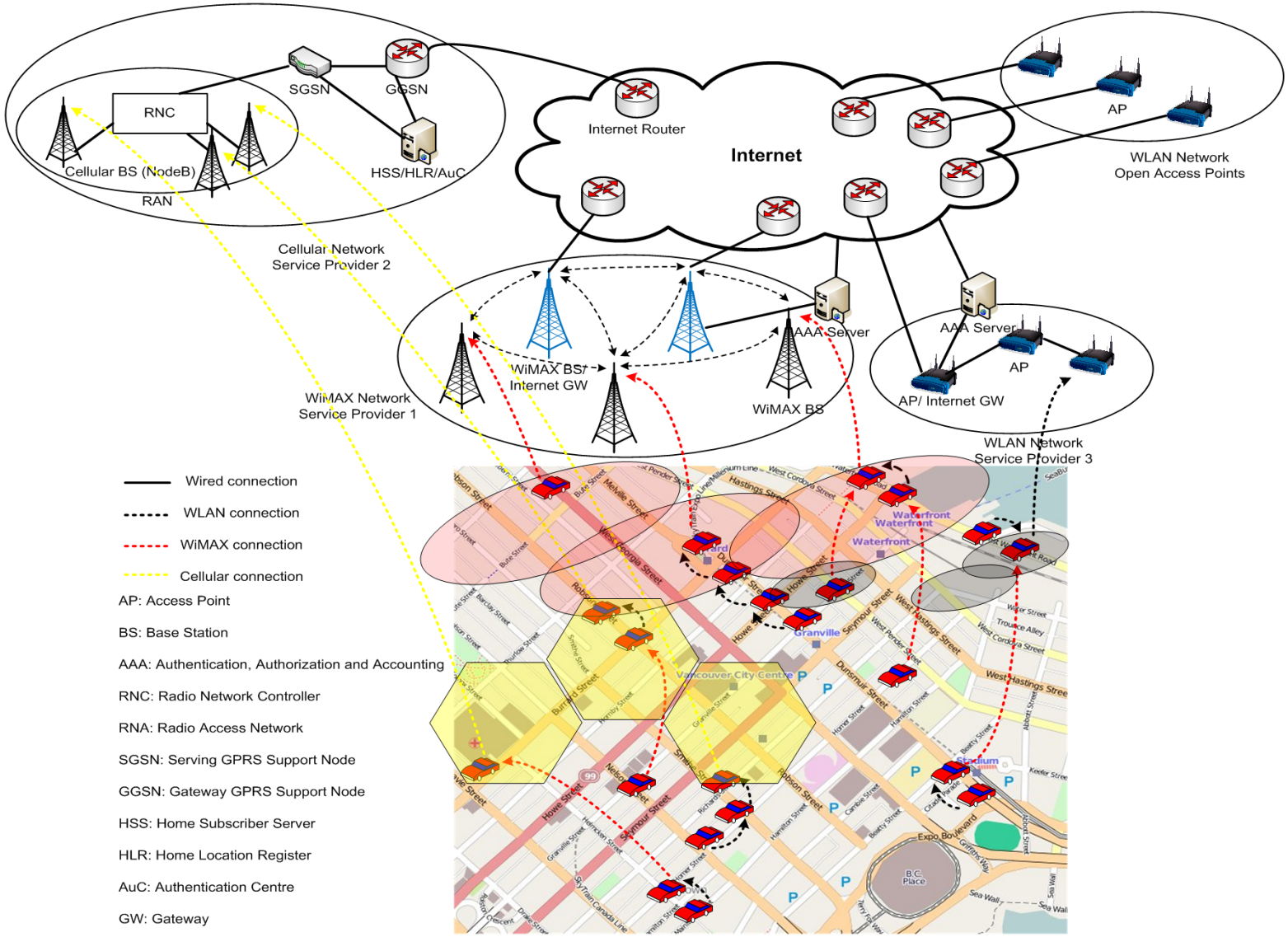
1. Cellular network only
2. Cellular + WLAN
3. Cellular + WLAN + ad hoc



Simulation Results



Ongoing Work – Routing in Vehicular Heterogeneous Networks



New Initiatives

- More vehicular networking:
  - Developing next generation Intelligent Vehicular networks and Applications (DIVA)
  - Centre of expertise and testbed for wireless freight security and efficiency (WiFSE)
- Next generation broadband wireless
  - Towards fourth generation wireless networks incorporating cognitive radios (NSERC CRD, PI: Robert Schober)
  - Cooperative design and resource allocation for wireless mesh networks (BCIC NRAS, PI: Vincent Wong)
  - Next generation broadband wireless access employing fibre-connected massively distributed antennas (NSERC SPG)
- Application specific wireless sensor networks
  - Wireless sensor networks for video surveillance (BCIC NRAS)
  - Enabling solutions for the future Canadian smart grid (NSERC SPG, PI: Juri Jatskevich)

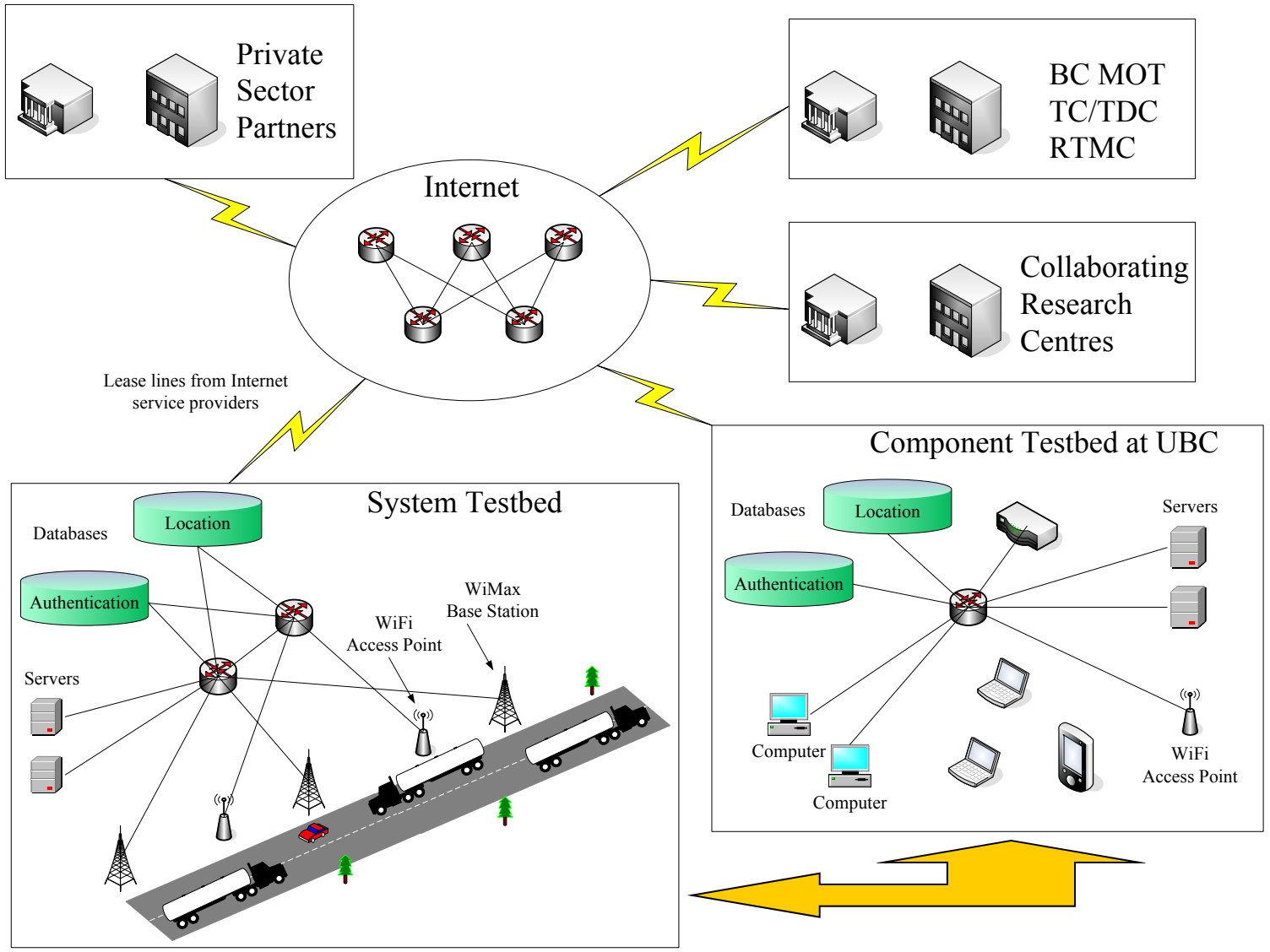
Developing Next Generation Intelligent Vehicular Networks and Applications

- NSERC Strategic Research Network, 2011-2015
- PI: Azzedine Boukerche, University of Ottawa
- 16 co-PI's from 9 Canadian universities
- $1M/year from NSERC, $280K/year from other sources
- Five themes:
  - Theme 1: Heterogeneous Vehicular Networks
  - Theme 2: Intelligent Vehicular Ad hoc and Sensor Networks
  - Theme 3: Multimedia Service Oriented Architecture for VANets
  - Theme 4: Vehicular and Sensor Network Security
  - Theme 5: Infrastructures and Applications for Vehicular Communications

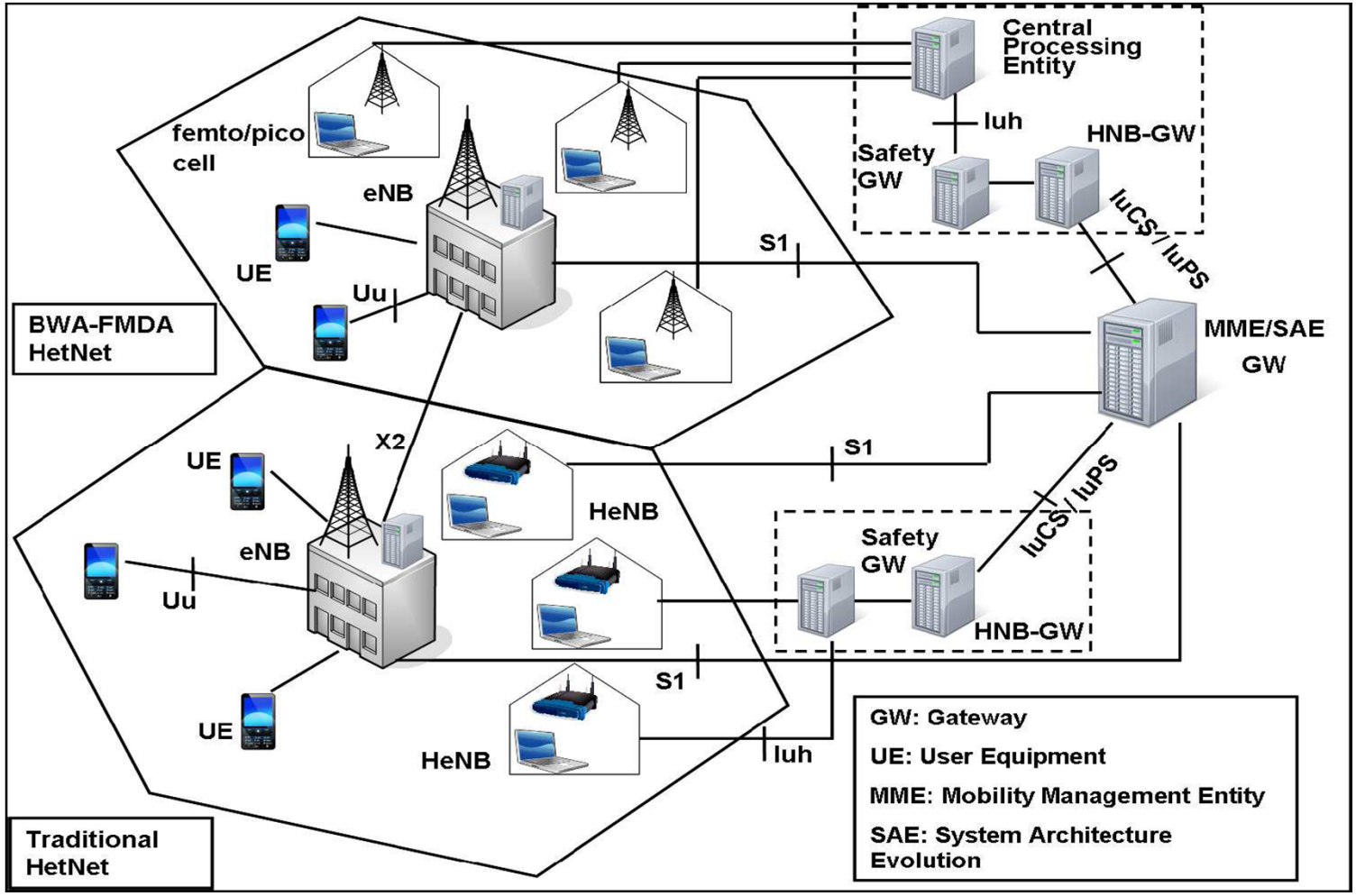
Potential UBC Projects in DIVA

- Heterogeneous vehicle-to-vehicle and vehicle-to-infrastructure system integration and evaluation strategies
- Harnessing vehicular social networks for crowd-sensing
- Intelligent transportation applications supporting secure and efficient movements of freights
- Secure and trusted terminals and network infrastructure

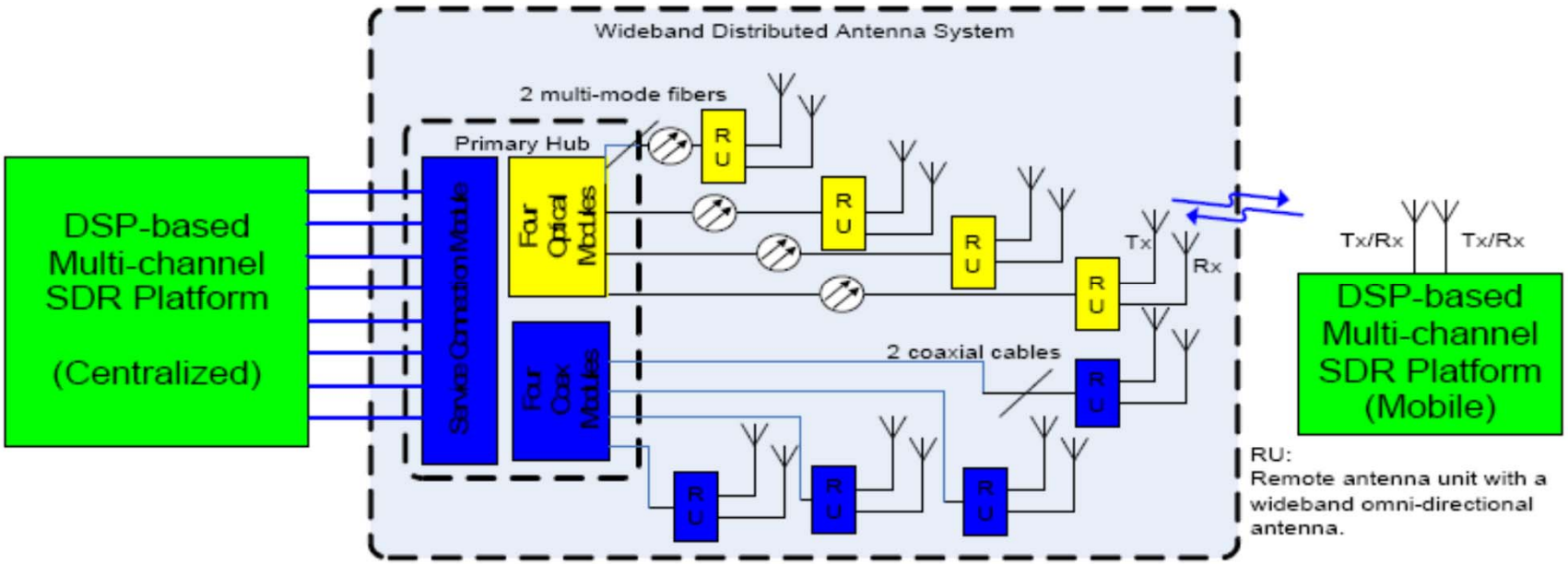
Proposed WiFSE CoE and Testbed



Next generation broadband wireless access employing fibre-connected massively distributed antennas (BWA-FMDA)

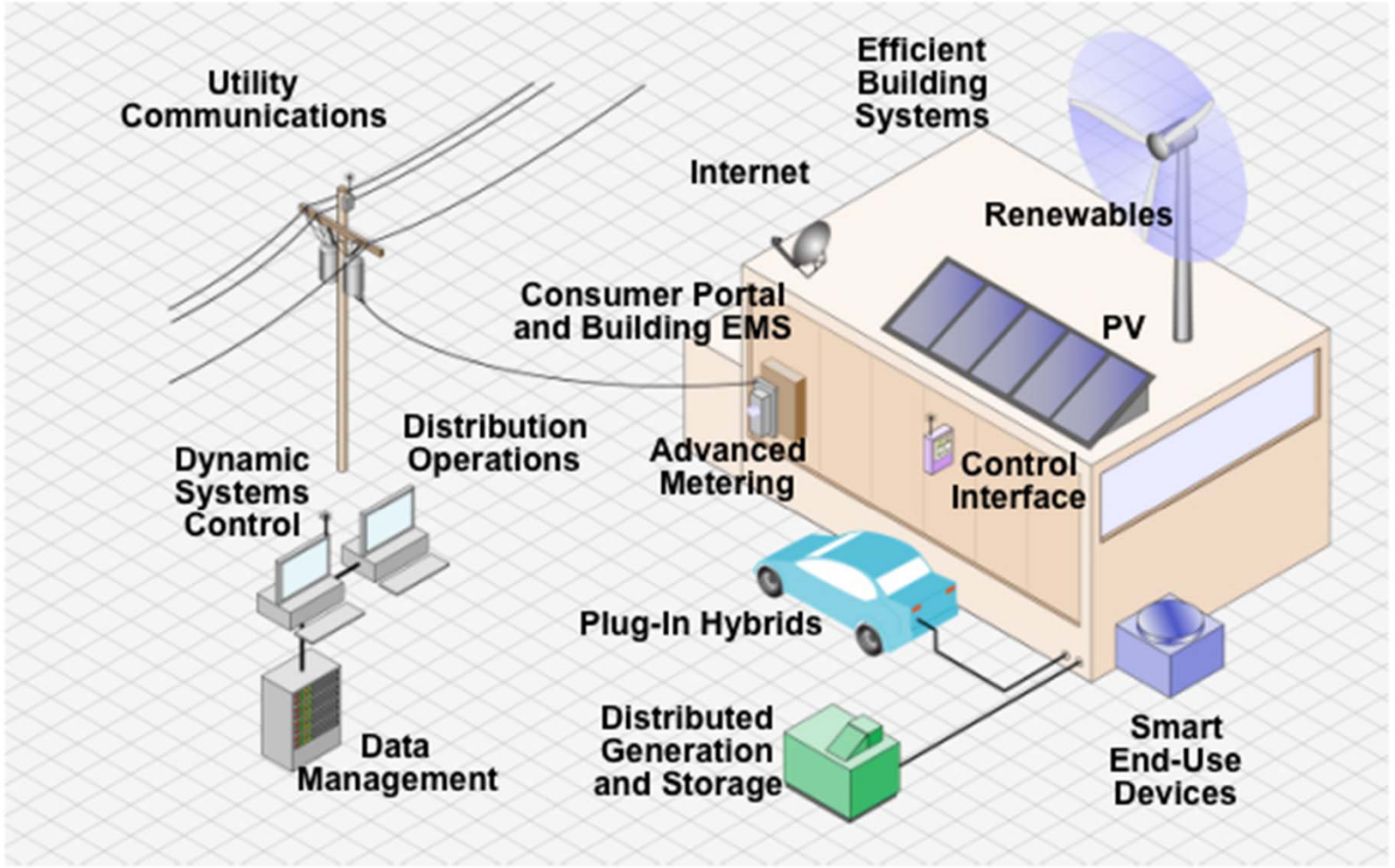


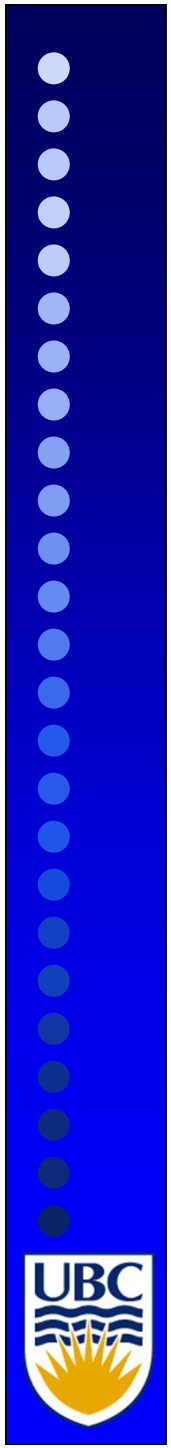
Testbed for BWA-FMDA



- CDN$150K Research Tools and Instruments grant approved
- Testbed consists of Zinwave DAS and powerful DSP-based DSR platform from Lyrtech

Enabling Solutions for the Future Canadian Smart Grid





Thank you!