# Y-Comm – A New Architecture for Heterogeneous Networking

## Part 1
## The Peripheral Framework

Glenford Mapp – Middlesex/Cambridge
Jon Crowcroft- Cambridge
David Cottingham- Cambridge
Fatema Shaikh-Middlesex

# Motivation

- A major shift in networking with the development of wireless systems
  - 3G, WLAN, WiMax, UltraWideBand
  - All systems working independently of each other
- Convergence  on IP at the network layer
  - All core networks will be based on IP
  - IP over ATM, IP over Fibre, etc

# Recent Developments

- Open Handset Alliance (OHA)
  - Started by Google, 34 Founding members
    - Contributing Android
    - Possible platform for this new architecture
- Verizon – big US telco
  - Allowing third-party mobiles on their network
  - So you just have to support the protocol stack
  - Run your own applications

# Network Evolution

- The proliferation of wireless systems at the edge of the Internet and the use of fast IP switching in the core.
- Core of the network
  - Fast (MPLS, ATM); mostly wired (fibre)
- Peripheral Wireless Networks
  - Errors due to fading, etc; not just congestion
  - Handover

# Handover is a serious operation

- Handover
  - Requires co-operation between the Mobile Node and the Network
  - A source of performance degradation
    - Needs to be carefully handled to be successful
- Handover Types
  - Horizontal handover – studied extensively
  - Vertical Handover – needs to be investigated in order to support heterogeneous networking

# Key Components of Vertical Handover

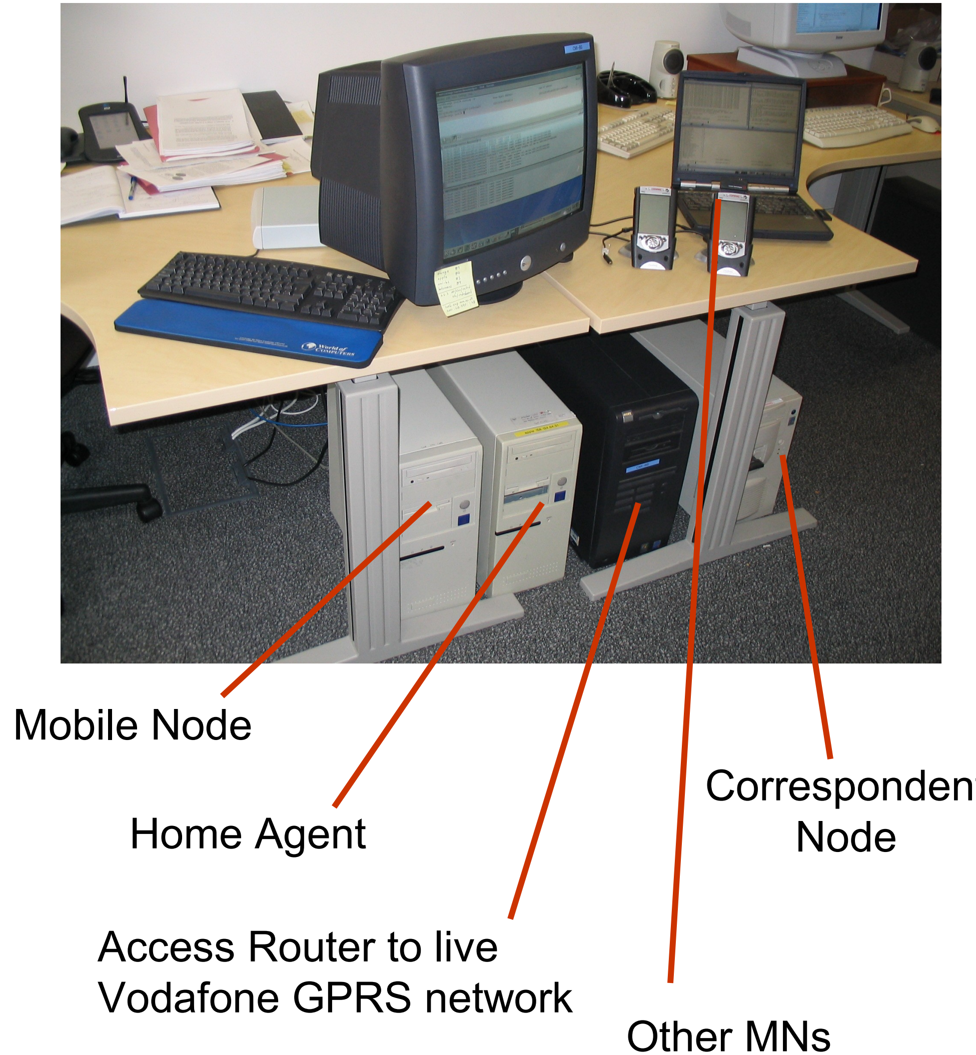
- Handover mechanisms
  - How to do vertical handover with minimal disruption
- Policy management
  - Deciding when and where to do a vertical handover
- Input triggers, states and events
  - How to get the data the system needs to make a decision on whether to do a handover

# Cambridge Wireless Testbed

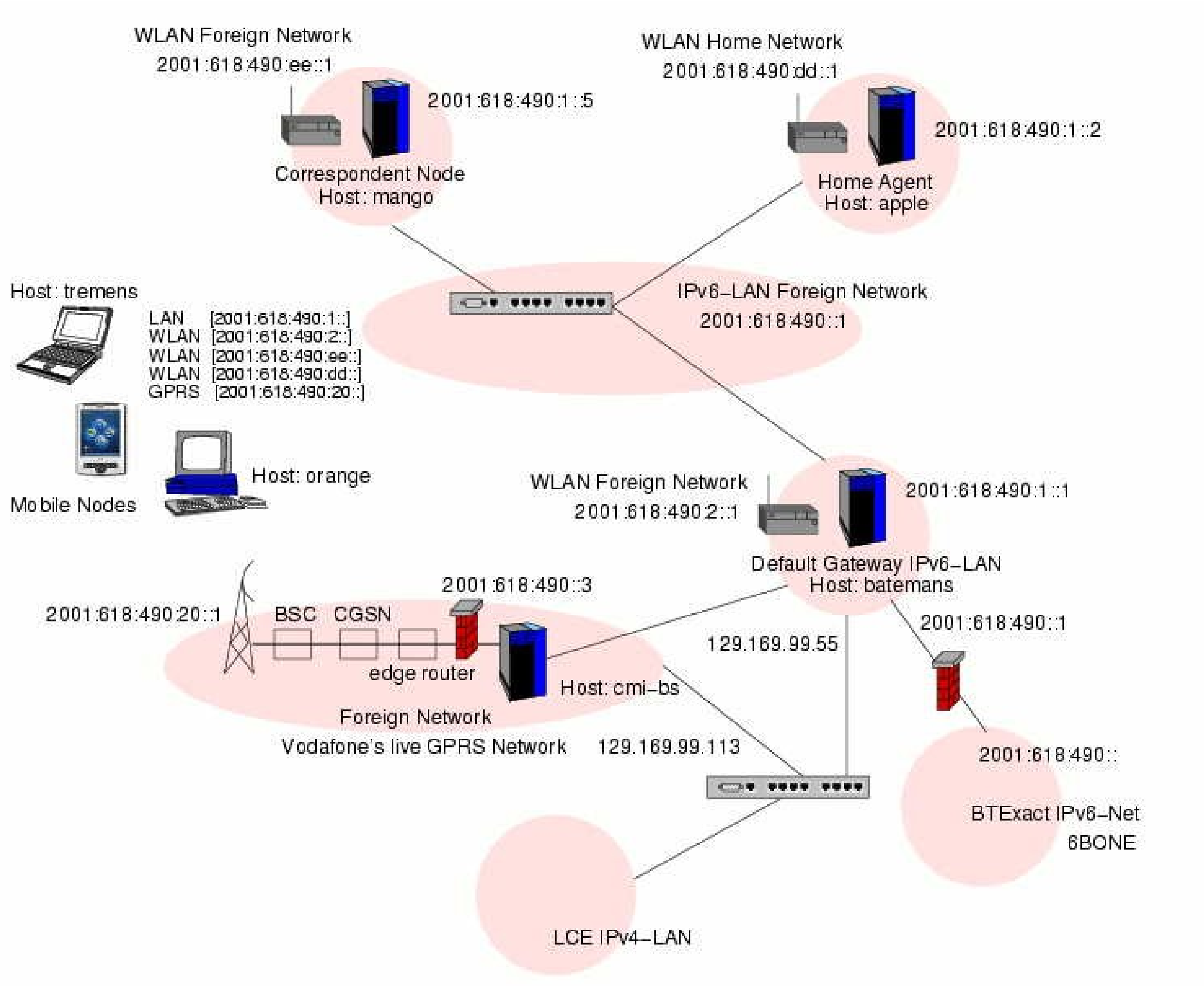
- Built in 2003 to study vertical handover
  - By Leo Patanapongpibul and Pablo Vidales
- Used an experimental 3G/GPRS network developed by Vodafone
- Used MIPv6 – connected to 6Bone
- 2 802.11b networks and an IPv6 wired network
- Various end devices
  - Fixed machines, laptops and iPAQs

# Equipment and Goals

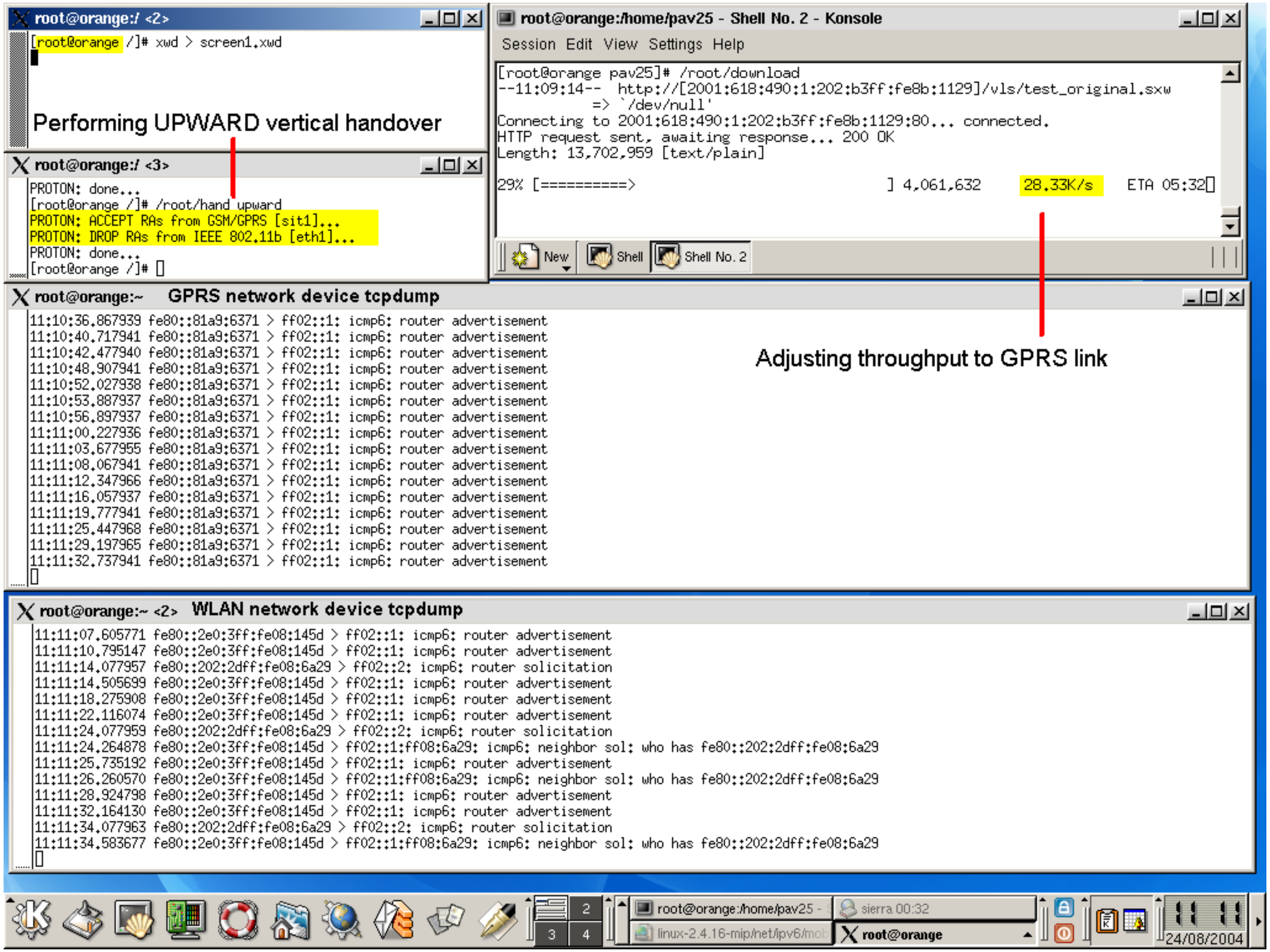
- Client-based solution for horizontal handovers
- MIPv6 performance during vertical handovers
- Improvements to vertical handover latency
- Policy-based solution to provide mobility support
- Policy-based solution to support multiple interfaces
- QoS-based vertical mobility
- Context-aware algorithms



# Cambridge Wireless Testbed



# Testbed Monitor



# Key Publications : available from:

http://www.cl.cam.ac.uk/Research/DTG/publications

- **L. Patanapongpibul, G .Mapp, A. Hopper,** An End System Approach to Mobility Management for 4G Networks and its Application to Thin-Client Computing, ACM SIGMOBILE Mobile Computing and Communications Review, ACM July 2006
- **P. Vidales, J. Baliosian, J. Serrat, G. Mapp, F. Stajano, A. Hopper**, Autonomic Systems for Mobility Support in 4G Networks. *Journal on Selected Areas in Communications (J-SAC), Special Issue in Autonomic Communications (4th Quarter)*, December 2005.
- **D.Cottingham and P. Vidales,** Is Latency the Real Enemy of Next Generation Networks, First International Workshop on Convergence of Heterogeneous Networks, July 2005
- **P. Vidales, R. Chakravorty, C. Policroniades**, PROTON: A Policy-based Solution for Future 4G devices. *5th. IEEE International Workshop on Policies for Distributed Systems and Networks (IEEE POLICY 2004)*, June 2004
- **L. B. Patanapongpibul, G. Mapp**, A Client-based Handoff Mechanism for Mobile IPv6 Wireless Networ. *8th IEEE Symposium on Computers and Communications (ISCC)*, IEEE Computer Society Press, June 2003.

# A Complete System for Heterogeneous Networking

- In order to build a complete system that
  - Does seamless vertical handover
  - Is extensible – seamlessly adds new technology
  - Is easy to develop new applications
- Requires a lot of work
  - Can't do this from scratch
  - Need to also look at what other people are doing
    - Ambient networks, etc
    - IEEE 802.21, etc

# A New Framework is needed

- Why?
  - Need to consider a lot of issues
    - Issues not covered by present reference models such as the OSI model
  - A way to think about building a complete system
  - Bring together different research efforts

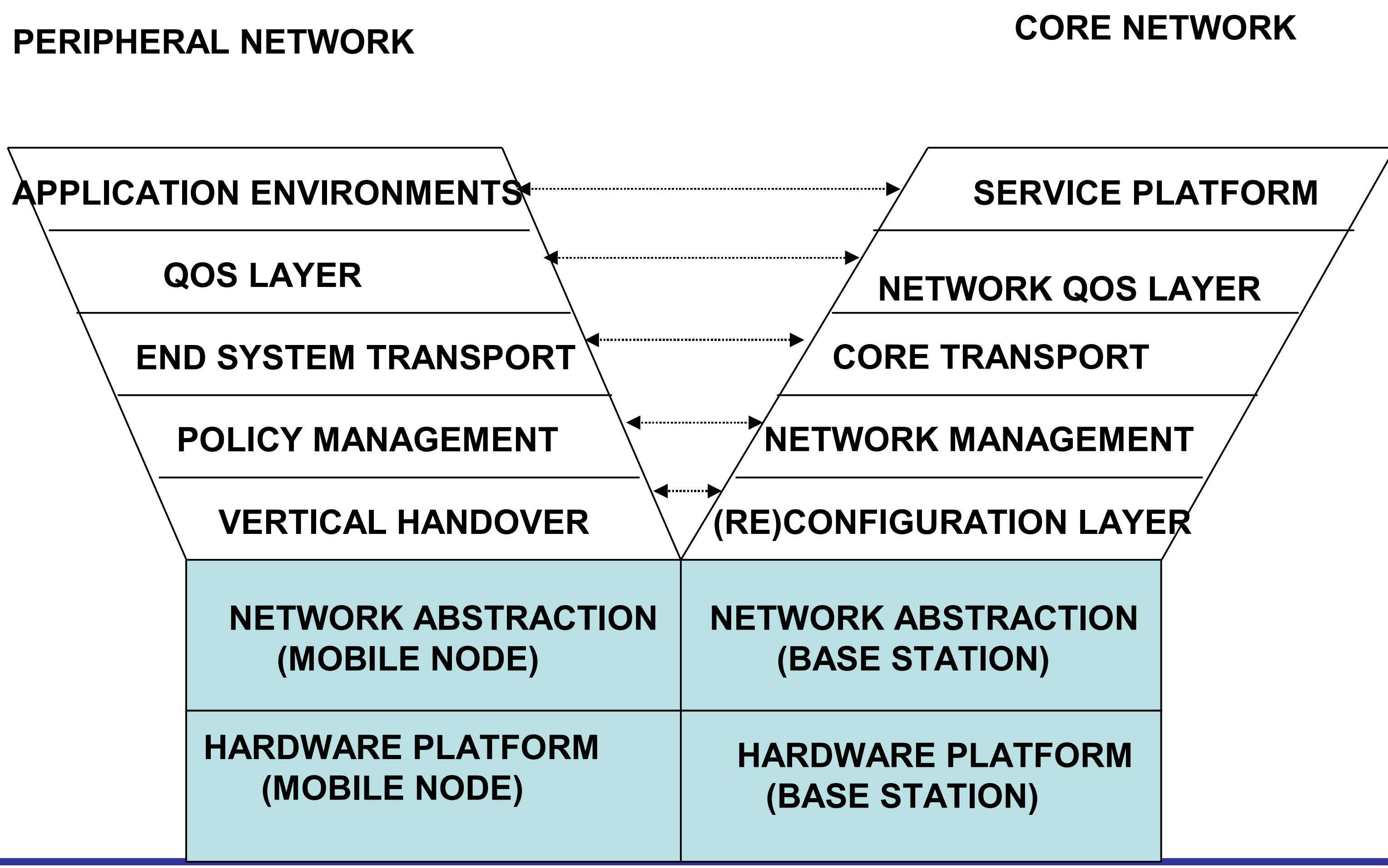
# Specifying the Framework

- Layered approach of the OSI model
  - Encase functionality in terms of layers
  - Can give a good hierarchical but modular model
  - We know that the layered approach has its problems
    - This is a reference not an implementation specification – so it is possible to squash layers together when implementing a real system
    - Need to be flexible

# We Need Two Not One!

- A framework for the Peripheral network
  - Represented by software running on the mobile node, supports:
    - Applications, QoS, Vertical Handover, support for several interfaces
- A framework for the Core network
  - Represented by software running in the network, supports
    - Programmable infrastructure, network management, QoS, Service Platform

# The Y-Comm Framework



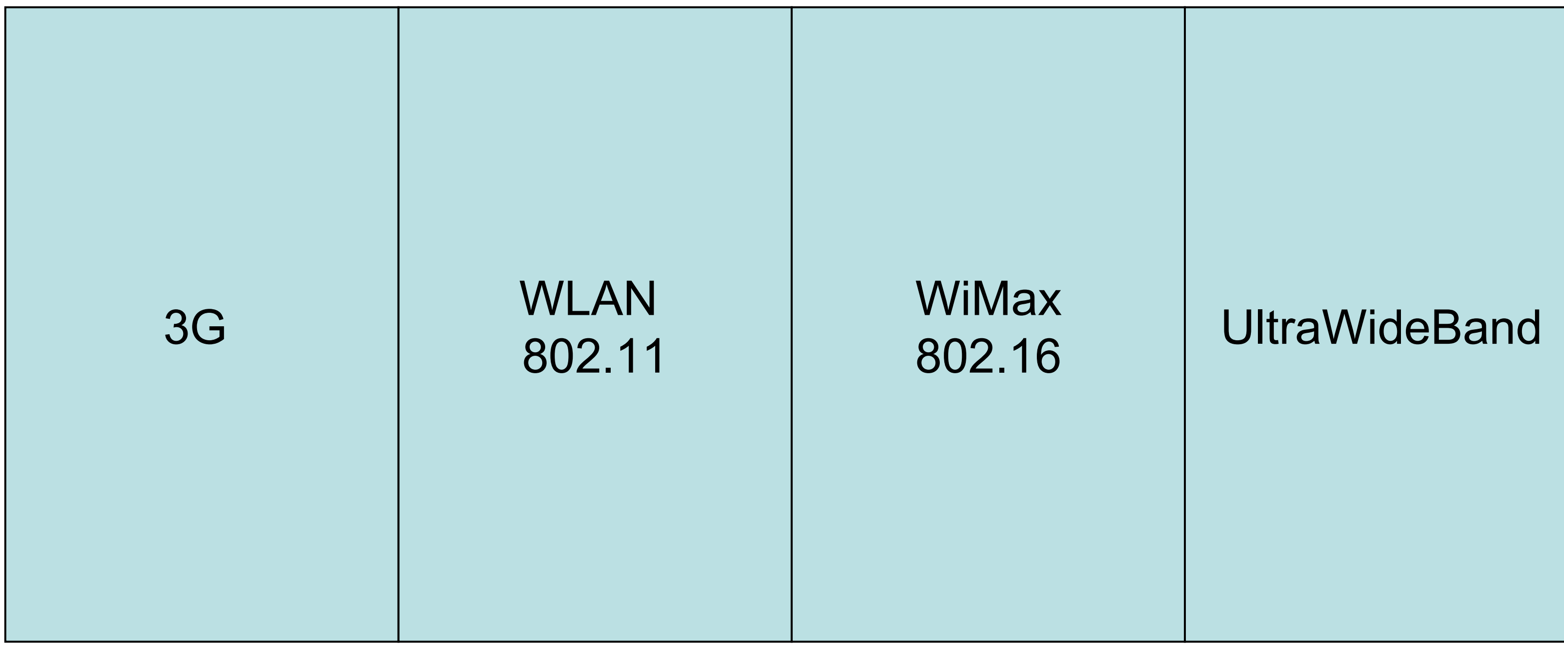
# The Peripheral Framework

| |
|---|
| APPLICATION ENVIRONMENTS LAYER |
| QOS LAYER |
| END TRANSPORT SYSTEM |
| POLICY MANAGEMENT LAYER |
| VERTICAL HANDOVER LAYER |
| NETWORK ABSTRACTION LAYER |
| HARDWARE PLATFORM LAYER |

# Layer 1: Hardware Platform Layer

- Hardware Platform Layer
  - Defines the physical requirements for a particular wired or wireless technology
  - Expanded physical layer
    - Includes electromagnetic spectrum
    - Modulation and channel reservation algorithms
  - Incompatibility issues
    - Two technologies may be incompatible and cannot be used simultaneously

# Hardware Platform Layer Represented as Vertical Components



# But this is all about to change!

- Need to make more efficient use of the electromagnetic spectrum
- Cognitive Radio
  - A radio that is aware of and can sense its environment, learn from its environment, and adjust its operation according to some objective function

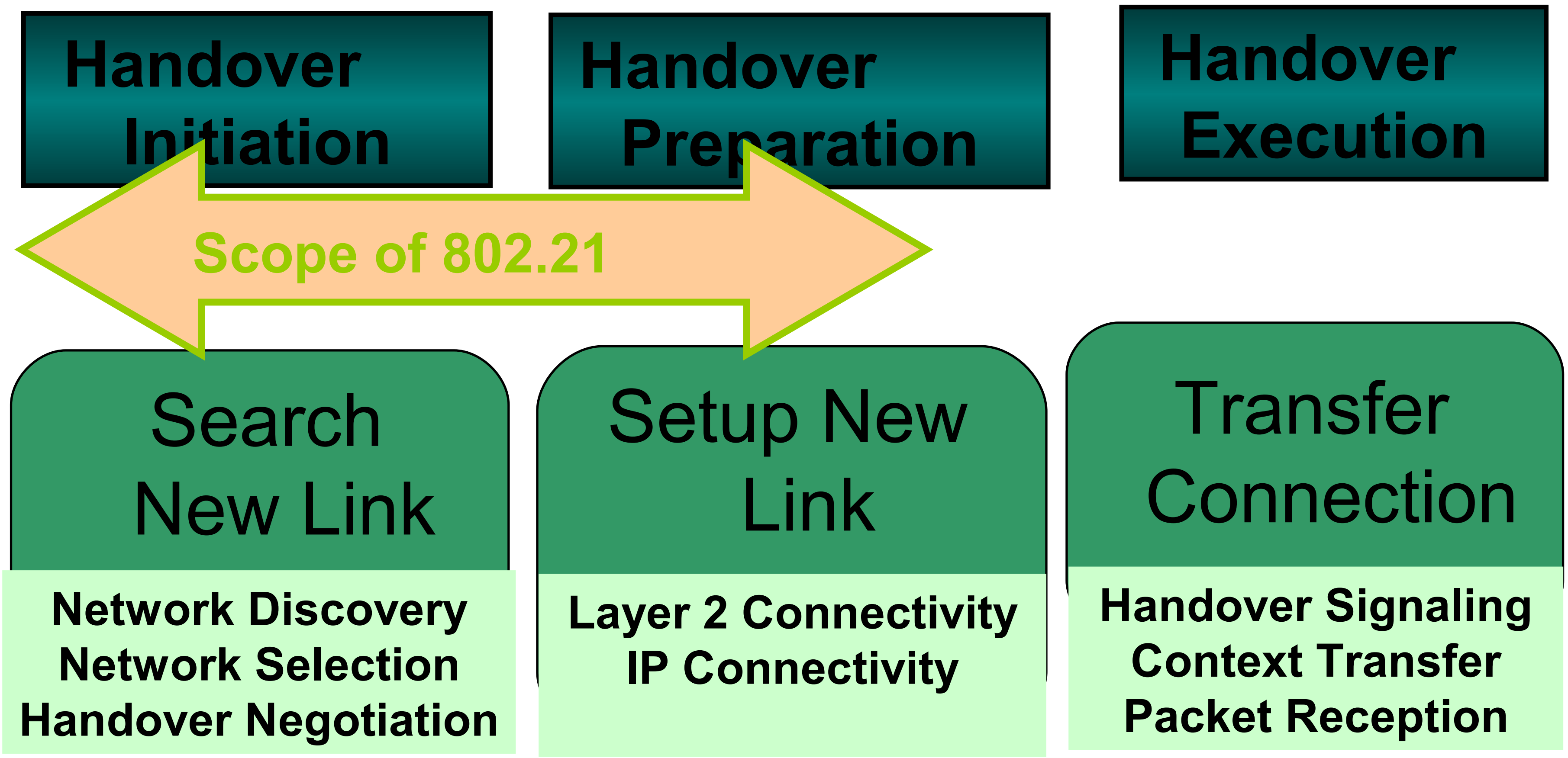
# Cognitive Radio (CR)

- Technology
  - Software Defined Radio (SDR)
    - Wide spectrum receiver
    - Do the processing in real-time
  - Intelligent Signal Processing (ISP)
    - Allows it to detect interference and move to another part of the spectrum
  - Ideal cognitive Radio – Mitola Radio > 2030
    - Mitola radio uses CR as the physical layer of a communications model
    - That's why CR is part of Y-Comm

# Layer 2: Network Abstraction layer

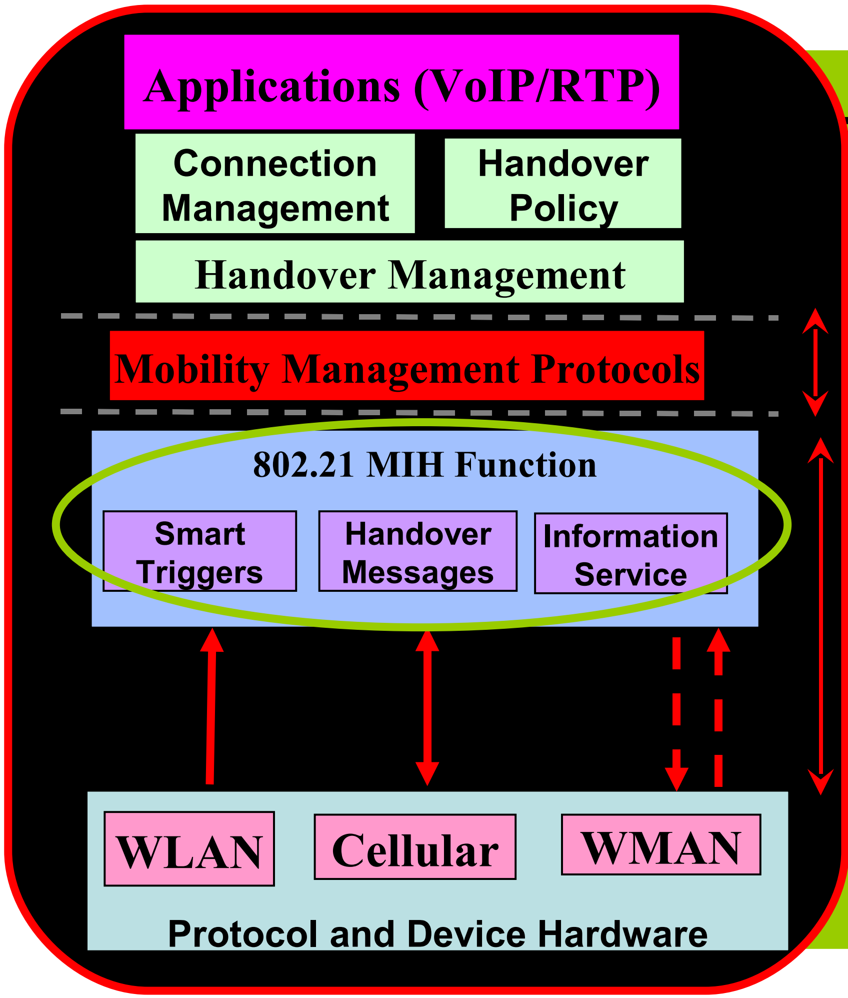
- Network abstraction Layer
  - An abstraction that allows us to define, control and manage any wireless network on a mobile host
  - Key issues: data path functions; data formats (Link-layer), turning features on and off
  - Need to generate L2 triggers when a new network is detected or when an old network is no longer detectable
    - Build on 802.21

# Genesis for 802.21




**IEEE 802.21 helps with Handover Initiation, Network Selection and Interface Activation**

# 802.21: Key Services




iggers
Change
redictive
Initiate

Network Information
Available Networks
Neighbor Maps
twork Services

mands
Initiated
Initiated
andovers

**802.21 uses multiple services to Optimize Vertical Handovers**

# Layer 3: Vertical Handover Layer

- Layers that define the mechanism for vertical handover.
- Support for different types
  – Network-based
  – Client-based

# Client-Based Handover

- More scalable for heterogeneous networks
  - Mobile node can monitor the status of all its network interfaces via the network abstraction layer
  - Can take into account other factors such as the state of TCP connections
    - Don't want to do a handover during the start and termination of TCP connections

# Layer 4: Policy Management layer

- Decides if, when and where vertical handover should occur.
- Different types:
  - Reactive
    - Depends on L2 events that inform the mobile node when it is entering or leaving a network.
  - Proactive
    - The mobile node can know or estimate the network state at a given point before it arrives at that point

# Layer 4: Advantages of Proactive Policies

- Proactive Policies allow us to maximize the use of available channels provided you know the amount of time a channel will be available.
- That time is known as:
  - Time before vertical handover (TBVH)
    - Can significantly reduce packet loss during all vertical handovers

# Layer 4: Proactive policies

- Proactive policies can themselves be divided into 2 types
- Proactive knowledge-based systems
  - Knowledge of which local wireless networks are operating at a given location and their strengths at that point
  - We also need a system to maintain the integrity, accessibility and security of that data

# Layer 4: Proactive Policies

- Proactive model-based policies
  - Design a simple mathematical model of the network, taking into account a signal strength threshold, the velocity and direction of the mobile node and the distance from the base station
  - It is possible to calculate when vertical handover should occur

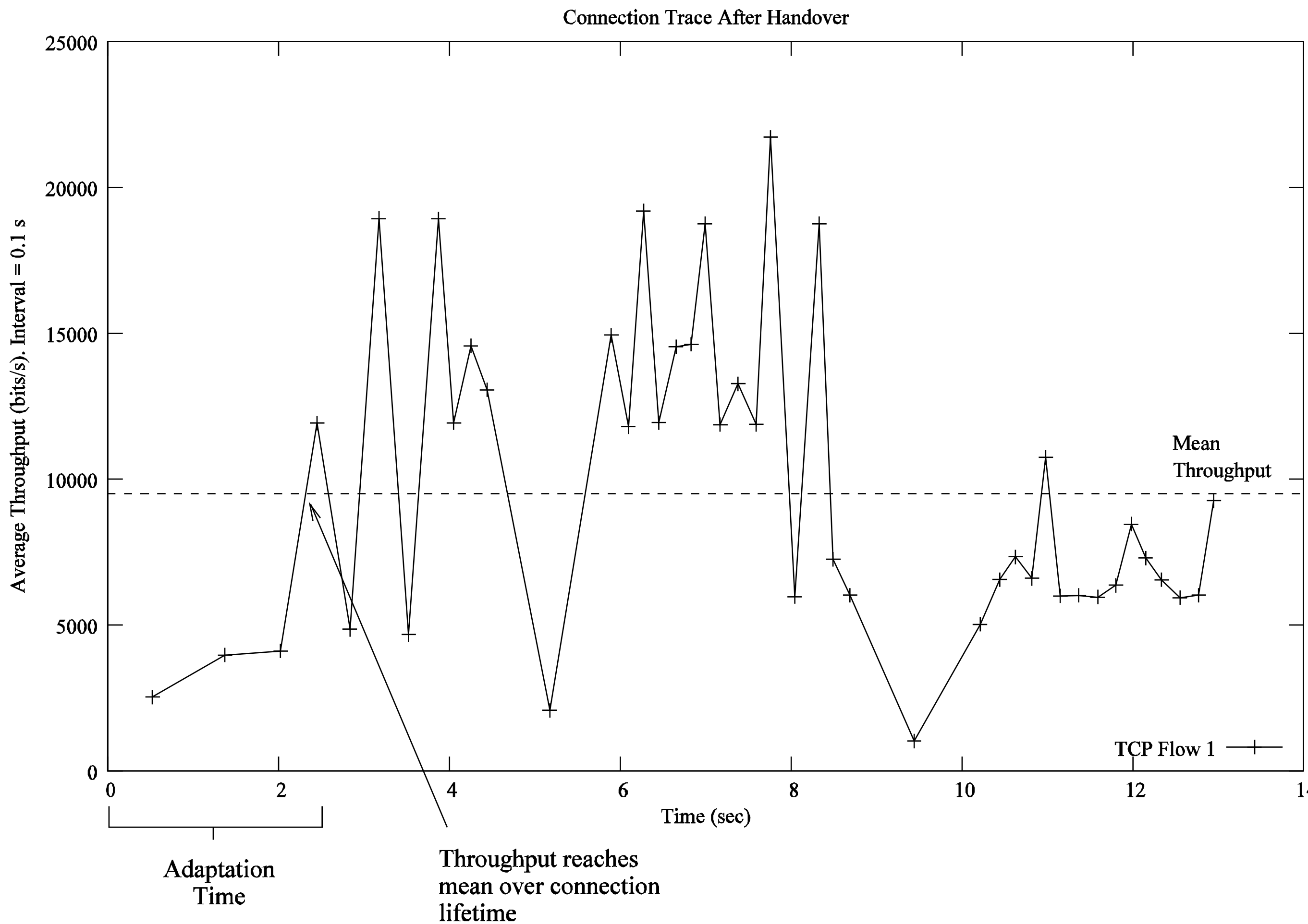
# Layer 5: End User Transport System

- Specifies how data is routed to individual hosts and transport protocols for error correction, reliability and Quality-of-Service requirements
  - Encompasses Layer 3 and Layer 4 in the OSI model
- Different approaches
  - Keep the same protocols as in the core network
  - Keep TCP/IP, but modify TCP
  - Don't modify TCP but try to get it to respond more quickly to network outages
  - Try a completely new protocol suite

# Layer 5: Continued

- Keep TCP/IP Unmodified
  - Leads to sub-optimum performance.
    - TCP assumes packet loss is only due to congestion and goes into slow start.
  - Work on the Cambridge Testbed indicates to the slow adaptation rate of TCP after vertical handover is a cause for concern
    - Need to fit the TCP protocol engine with triggers

# Layer 5: Slow Adaptation of TCP After LAN->GPRS Handover



# Layer 5: Continued

- Keep TCP/IP but modify TCP
  - I-TCP, M-TCP
  - TCP Extensions for Immediate Retransmissions (Internet Draft)
- Don't modify TCP but build mechanisms so that it could respond more quickly to media outages
  - Smart Link Layer (Scott and Mapp 2003)

# Layer 5: The case for a new transport Infrastructure

- A new transport system could be more suited for wireless networking
- Do all machines have to have an IP address to use the Internet?
  - No.. Look at Network Address Translation (NAT)
  - Translation is done between a private address and port to a global address and port at the NAT server

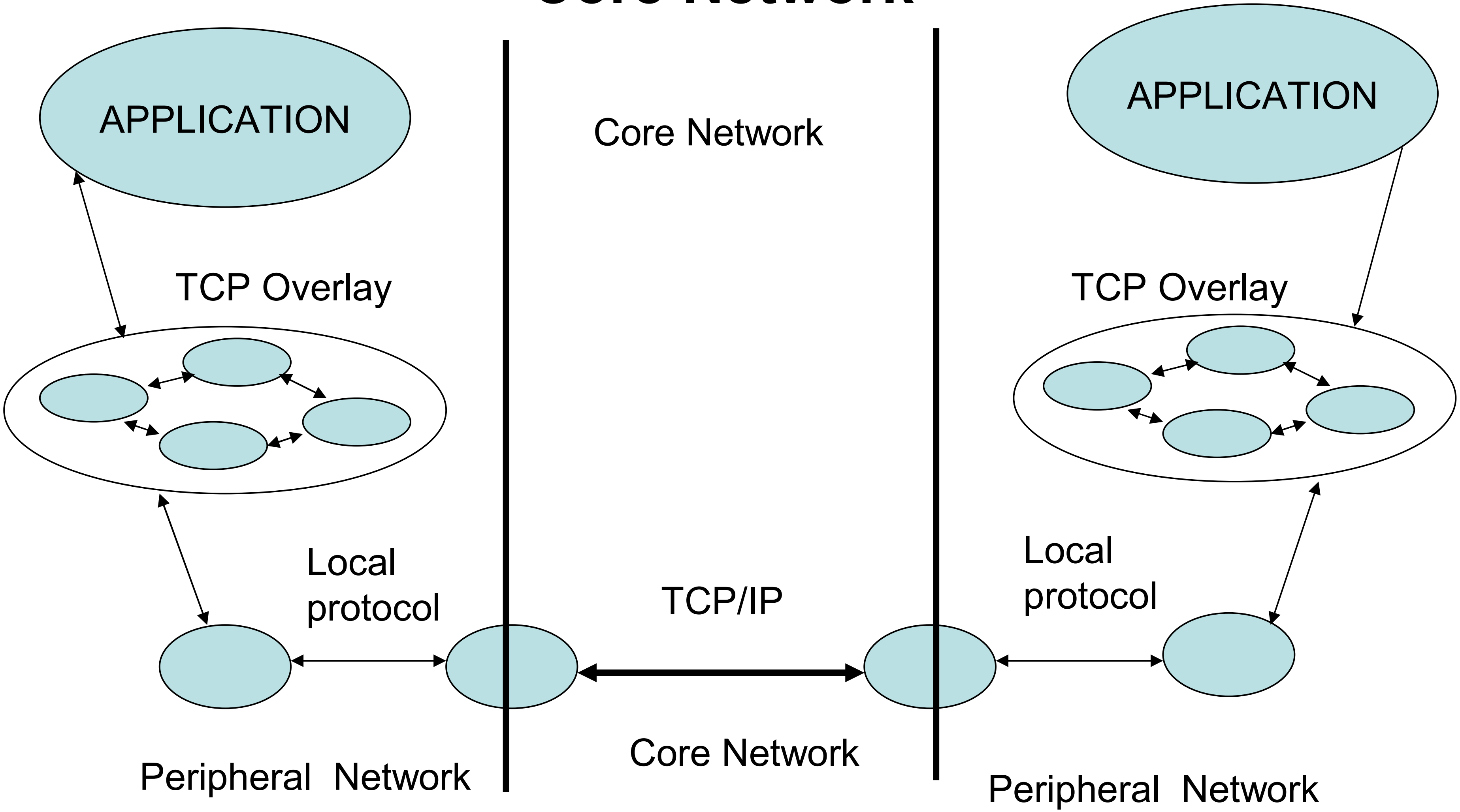
# Layer 5: Continued

- A global IP address in the case of NAT is really being used as an endpoint in the core network
- So we can use another network scheme in the peripheral network once we can specify how we map it to TCP/IP or UDP/IP in the core network

# Layer 5: Application Conformance

- You don’t want to recompile all your applications for this new framework
- Concept of a TCP protocol interface
  - Key idea is that TCP becomes an interface so that the TCP engine forms an overlay above the actual protocol running in the network. So the application thinks it’s running TCP/IP but there is another protocol “under the hood”.

# Layer 5: TCP as a Protocol Interface in Peripheral Networks but a real protocol in the Core Network



# Layer 6: QoS Layer

- QoS is the most dynamically changing component in heterogeneous networking
- Applications running on heterogeneous devices need support to handle this
- Two Concepts of QoS
  - Downward QoS
  - Upward QoS

# Layer 6: Downward QoS

- Mainly to support legacy applications
- The application specifies a minimum QoS and the QoS layer does the mapping between the QoS that the application requires and the QoS that is currently available - but is dynamically changing

# Layer 6: Upward QoS

- For applications that should adapt to changes in QoS, e.g. Multimedia services, etc
  - The QoS layer therefore signals the application using an event mechanism to indicate changes in the available QoS
  - Applications can specify routines that will be called when the events occur
    - Similar to the X Window System

# Layer 7: Application Environment Layer

- Allows users to build applications using this framework
- Keen on using the Toolkit approach which allows us to build different application environments for different situations
  - e.g. an application environment for highly mobile video applications, etc.

# Work already done

- Most of the work has been done in the Peripheral Framework
  - Client-based handoff – Leo
  - Policy Management
    - PROTON – Pablo
    - Proactive Policies
      - Knowledge-based – Sentient Vehicle Project
      - Model based approach – Middlesex
    - Downward QoS

# Handover mechanism for the Cambridge TestBed - Leo

- Augmented Mobile IPv6
- Uses Router Advertisements (RA)
- Stores all the RAs from the various networks in an RA cache
  - Signal strength, time, router metric
- Selects the best for handover
- Checks TCP connections

# Defines two different types of Handovers

- Anticipated Handover
  - There is another base station to which to handover
  - So you are getting RAs from that base station
- Unanticipated Handover
  - There is no other base station in sight and the signal strength for the current base station is falling fast

# Just before Handover

- We need to be able to reactivate TCP connections once we get a new IP address
- Anticipated handover
  - Save the last TCP acknowledgement for each connection
- Unanticipated handover
  - advertise a zero window

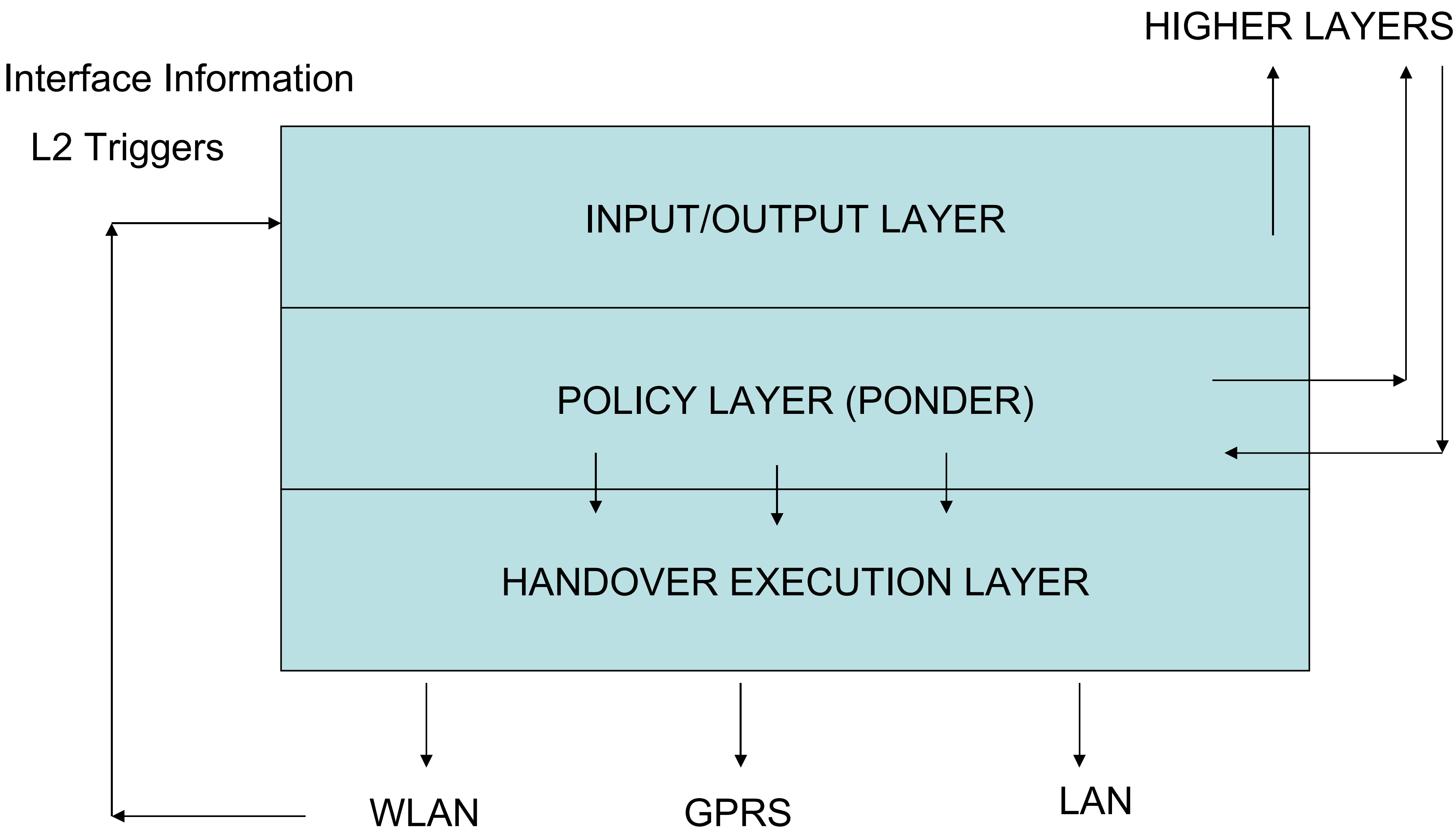
# Handover in the Cambridge Testbed

- Does the Handover
- Gets a new IP address and then sends a Binding Update to the CN.
- For anticipated Handover, we send the last TCP ACK packet for the connection three times.
  - This triggers the fast-retransmit mechanism
- For unanticipated handover, we advertise a non-zero window

# Proton: A Reactive Policy Mechanism - Pablo

- Three level structure
  - Lowest layer – Handover execution layer
    - Actually does the handover
  - Middle layer – Policy mechanism
    - Written in PONDER (Imperial College)
  - Top Layer – Input/Output Layer
    - Relevant Events and Triggers for the policy layer
    - Provide information for the higher layers

# Understanding PROTON



# Proactive Policies

- Knowledge-based approach (David Cottingham)
- Gather a database of the field strengths for each network around Cambridge
- Need to maintain the database and also know how the results might be affected by seasonal effects

# The Sentient Van (Cambridge)

# Proactive Policies

- Using a simple mathematical model
- Define a radius at which handover should occur
- Find out how much time I have before I hit that circle, given my velocity and direction
- Calculate TBVH
  - Used simulation (OPNET)
  - Can be used in the real world as well as in simulation

# Predictive Mathematical Model for TBVH (Simple Case)

Movement of MS under BBS coverage (upward vertical handoff)

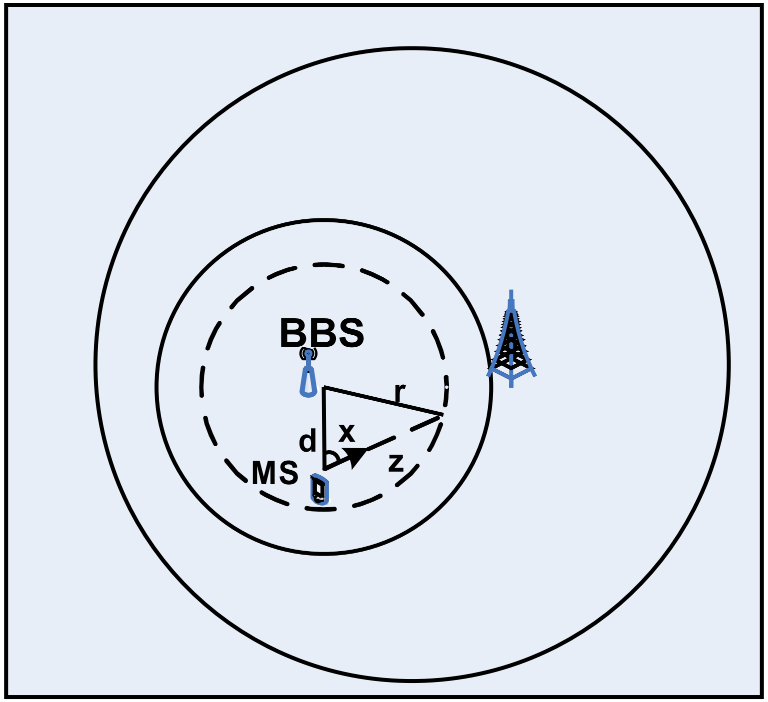
- Introduction of additional functionality to Base Station at network boundary (BBS).

- Distance between MS and BBS derived from location co-ordinates or

$$RSS_{dB} = -10\gamma \log(l)$$

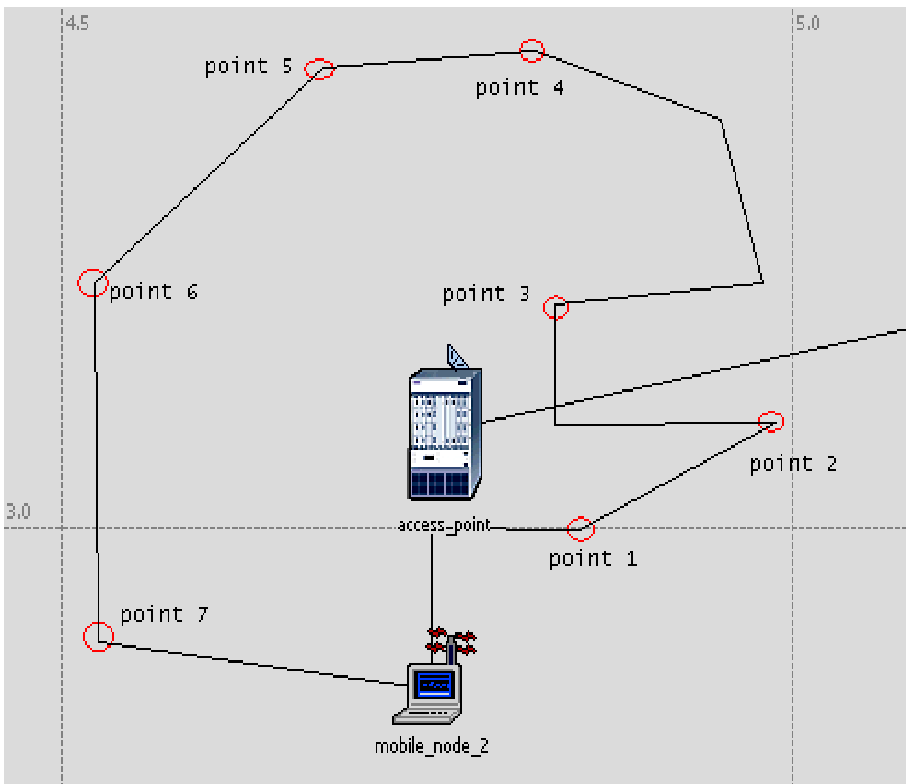
- Estimated TBVH

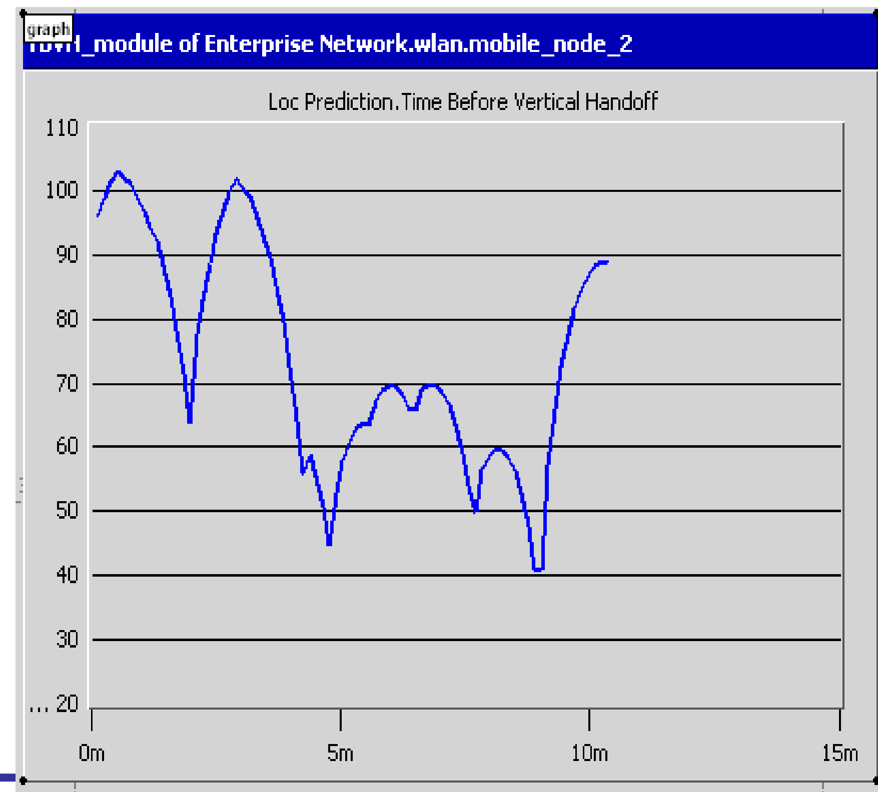
$$TBVH = \frac{\sqrt{r^2 - d^2 \sin^2 x} \pm d \cos x}{v}$$



# Simulation and Results

TBVH simulation in OPNET Modeler:



# Downward QoS Management

Downward QoS management requires answers to several key issues including:

- QoS requirements of application streams
- Suitable networks for allocating a call
- Current and likely future conditions of available networks
- Duration for which networks may be available

Important for MN to improve context awareness before bundling traffic streams over channels

# Stream Bundle Management Layer

- Specialised proactive layer residing in QoS Plane of MN
- Consists of set of policies for management and scheduling of multi-class traffic streams onto different available channels based on
  - application priority
  - device mobility patterns
  - existing network and transport conditions
- Adopts a refined approach of call management on per-flow basis.

# Traffic management in SBM Layer

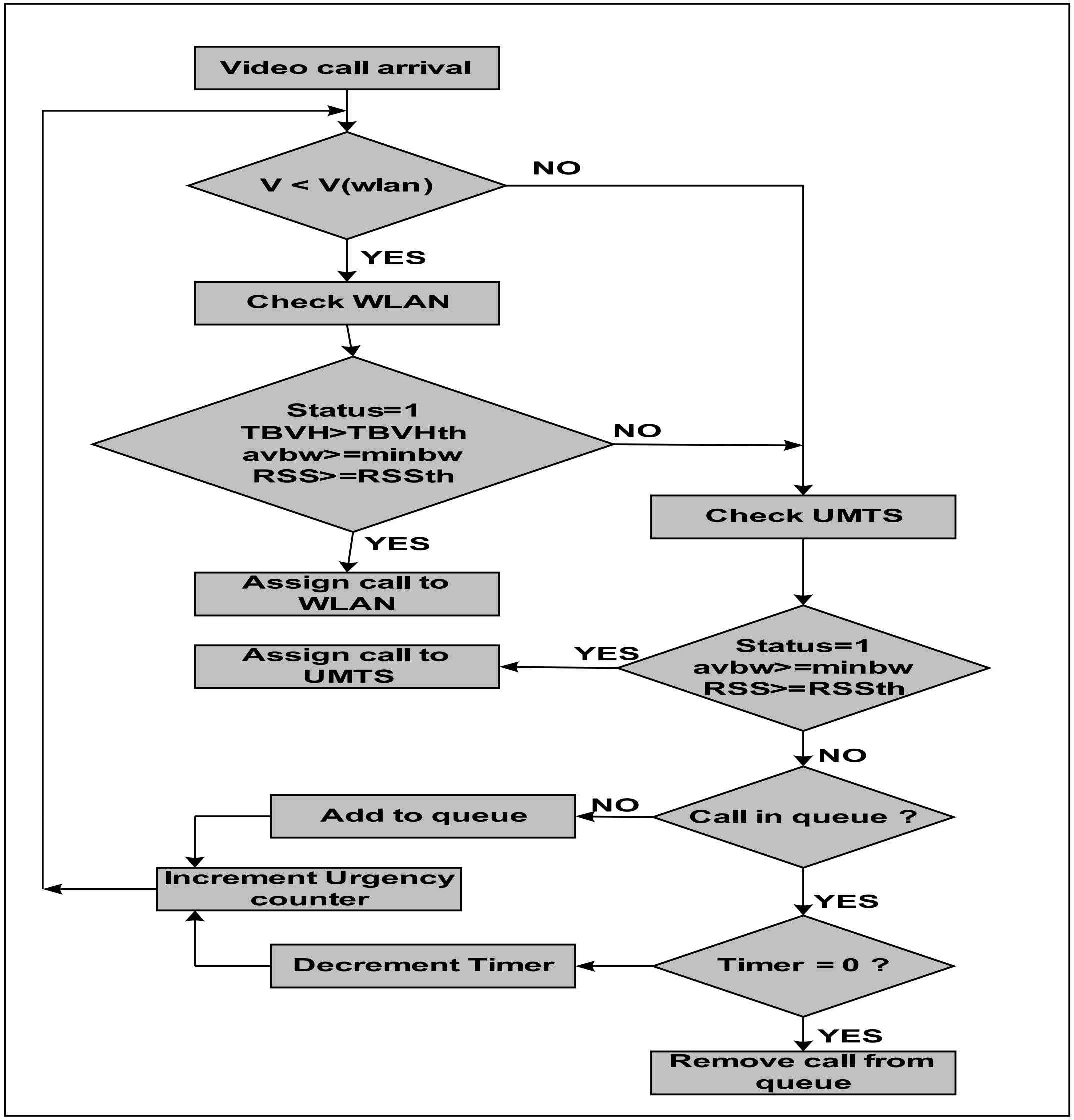
- Network context information for each interface stored in the Network Descriptor Matrix

$$\begin{matrix} NWid_1 & status_1 & avbw_1 & RSS_1 & TBVH_1 & RTT_1 \\ NWid_2 & status_2 & avbw_2 & RSS_2 & TBVH_2 & RTT_2 \\ NWid_3 & status_3 & avbw_3 & RSS_3 & TBVH_3 & RTT_3 \\ NWid_4 & status_4 & avbw_4 & RSS_4 & TBVH_4 & RTT_4 \\ NWid_5 & status_5 & avbw_5 & RSS_5 & TBVH_5 & RTT_5 \end{matrix}$$

- Prioritised list of compatible networks for each traffic type

- TBVH plays important role in deciding choice of network and resources allocated to traffic stream.

# Traffic management in SBM Layer



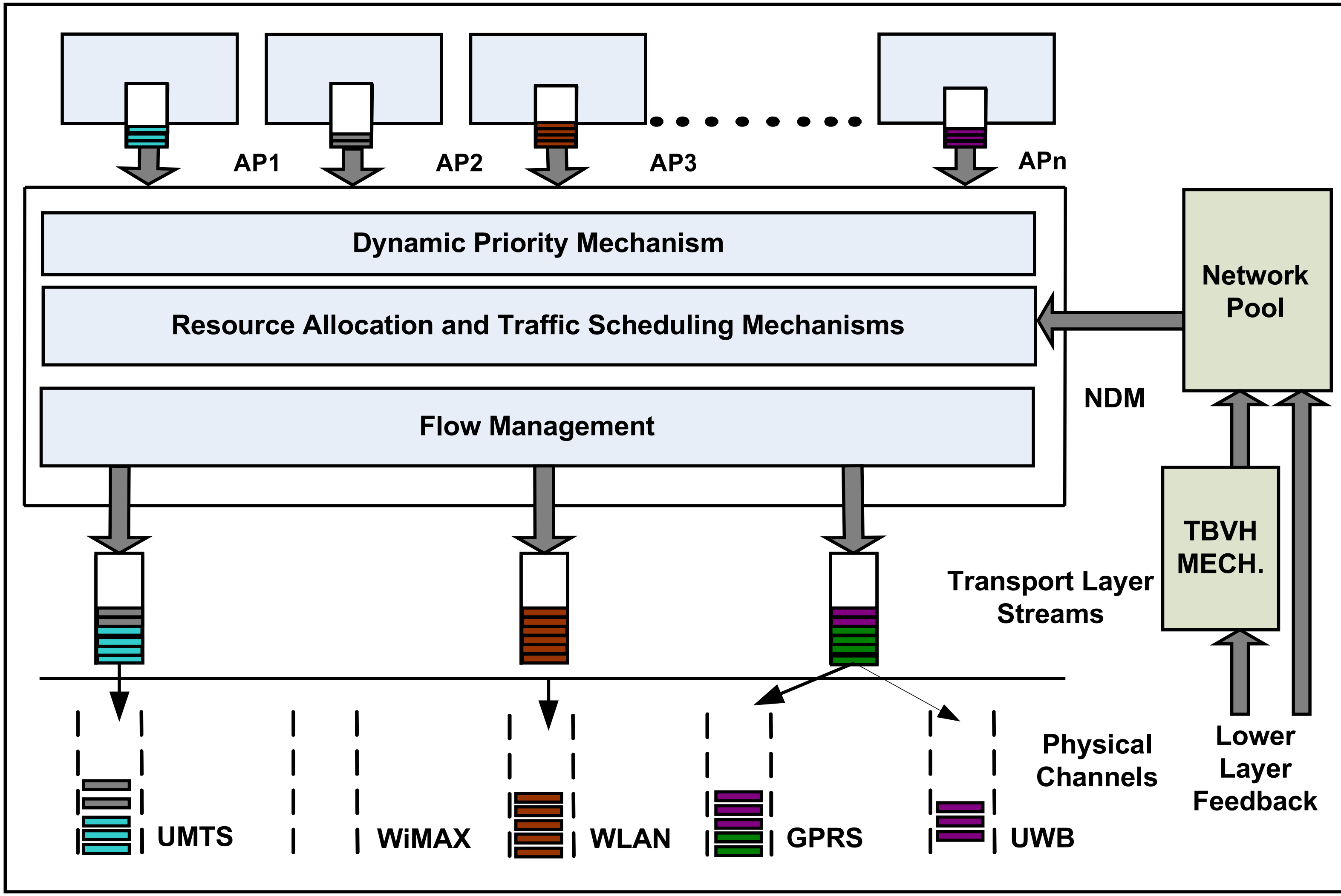
# Traffic management in SBM Layer

- Proposed Weighted Resource Allocation scheme:

(TBVH x W1) + (UV x W2) + (V x W3)

UV – urgency value
V – speed of MN, and
W1+ W2 + W3 = 1

# Stream Bundle Management Layer



# Current Work on the Peripheral Network

- Transport Layer
  - Looking at network issues (Jon Crowcroft)
  - New Transport Protocol (Glenford Mapp)
    - X4
- QoS Layer
  - Upward QoS
    - Building QoS-aware middleware (Aisha Elsafty)
      - Used this to build an application layer