Daedalus/GloMop
Architectural Walkthrough

Daedalus Retreat, Lake Tahoe
June 18-20th, 1996

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Outline

• Motivation and overview
• Core architecture components
• Core architecture walkthrough
  – connection, document retrieval, vertical handoff, document refinement
• Extended architecture components
• Extended architecture walkthrough
  – connection and authentication, vertical handoff, horizontal handoff, dynamic adaptation, load balancing, domain and network services
• Summary, Open Issues
Outline

• Motivation and overview

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• Summary, Open Issues
Motivation

• **mobility-aware network services**
  – seamless roaming (overlay IP)
  – efficiency of protocols and of handoff

• **mobility-aware application services**
  – dynamic adaptation to variability
  – enable a wide array of client devices

• **mobility-aware domain services**
  – resource discovery
  – load balancing
  – metering
Challenges

• **cohabitate with existing infrastructure**
  – Mobile IP, TCP, HTTP, Kerberos, ...
  – justify custom protocols

• **a scalable architecture**
  – network and proxies should support many clients

• **integrable but independent components**
  – pieces of the architecture should be able to function on their own
  – integration yields optimization and new capability
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• **Summary, Open Issues**
Core Architecture Components

- mobile host
  - Application Support
  - Custom MH Network Stack

- base station / FA
  - Custom BS Network Stack

- proxy host / HA
  - Proxy
  - Unmodified Network Stack

- corresponding host
  - content server

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Core Daedalus Mobile Host Components

- Application, Presentation, Session Layers
  - Unmodified App
  - Control Panel

- Transport Layer
  - TCP / UDP

- Network Layer
  - Overlay IP
  - mobile IP

- Data Link Layer
  - IR
  - RF
  - multiple interfaces

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  - content server
Core Proxy Architecture

Distiller

mobile
unmodified application
control panel
tcp/udp
control interface
overlay ip
ir rf ...
proxy
proxy
application-specific protocol
application-specific protocol
content server

TCP/UDP
IP
Ethernet

TCP/UDP
NOW

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Connecting to the Network
(core architecture - Mobile IP)

mobile host
control panel
control interface
TCP/UDP
Overlay IP
IR RF ...

base station
beacon
c Control interface
Overlay IP
Ether RF ...

foreign agent
Mobile IP
Ethernet
new care-of address

home agent
Mobile IP
Ethernet

registration request
Connecting to the Network
(core architecture - Mobile IP)

mobile host

foreign agent

base station

home agent

Overlay IP

TCP/UDP

control interface

unmodified application

control panel

mobile host

foreign agent

base station

home agent

Overlay IP

TCP/UDP

control interface

unmodified application

control panel

mobile host

foreign agent

base station

home agent

Overlay IP

TCP/UDP

control interface

unmodified application

control panel

mobile host

foreign agent

base station

home agent

Overlay IP

TCP/UDP

control interface

unmodified application

control panel
Document Request

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Document Download and ‘Chunking’

- Distiller
- TCP/UDP
- IP
- Ethernet
- HTTP
- content server
- Proxy
- TCP/UDP
- IP
- Ethernet
- mobile
- web browser
- control panel
- control interface
- overlay IP
- IR
- RF
- ...
Distillation

- Distiller
- mobile control panel
- web browser
- control interface
- TCP/UDP
- overlay IP
- IR, RF, ...
- Proxy
- TCP/UDP
- IP
- Ethernet
- content server
Vertical Handoff from IR to WaveLAN
(core architecture)
Handoff Subroutine
(core architecture)
Handoff Subroutine
(core architecture)

- Mobile host
  - Control panel
  - Unmodified application
  - Control interface
  - TCP/UDP
  - Overlay IP
  - IR
  - RF
  - . . .

- Foreign agent
  - New bs
  - Acknowledgement

- Home agent
  - Old bs

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Handoff Subroutine
(core architecture)
Handoff Notification and Dynamic Adaptation

- Distiller
- Proxy
- Content server
- (average) network characteristics
- UDP packet
- Control panel
- Overlay IP
- IR, RF, ...
- TCP/UDP
- IP
- Ethernet

Manual handoff command

Mobile

Web browser

TCP/UDP
‘Chunk’ Refinement

Distiller

Mobile

Refinement request

HTTP "get"

Proxy

Content server

Web browser

TCP/UDP

Overlay IP

IR

RF

...
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  - Proxy
  - Custom Proxy Network Stack

- Corresponding host
  - Content server
Extended Architecture Components

mobile host

Application Support
Custom MH Network Stack

proxy host / HA

Proxy
Custom Proxy Network Stack

base station / FA

Custom BS Network Stack

corresponding host
content server

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Extended Daedalus Base Station

Dynamic Allocation (Class-Based Queuing)

mobile IP, decapsulation, multicast handoff buffers

TCP Snoop

Overlay IP

Control Interface

beacond decapd

Network Layer

Data Link Layer

Ethernet RF ...

wired and unwired interfaces
Extended Daedalus Proxy

Application, Presentation, Session Layers

Transport Layer

TCP / UDP

Overlay IP

Network Layer

Data Link Layer

Ethernet

Proxy

Delivery Classes

UDP

Control Interface

network connection monitor

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Extended Service Architecture

- Domain services
  - Authentication
  - Metering & Credit
  - Subnet Manager
  - Mobility database
- Subnet services
  - Foreign agent
  - Resource Manager

- Mobile host
- Proxy host
- Base stations
- Corresponding host
Extended proxy architecture

PTM
Distiller
NOW

mobile

proxy

unmod app
GloMop app
control panel
GloMop
TCP/UDP
deliv. classes
control interface
overlay IP
cbq
IR
RF...

TCP/UDP
overlay IP
GloMop
HTTP
POP3
GloMop
Proxy
Ethernet

TCP/UDP
deliv class
control interface

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Connecting to the Network
(Multicast)

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Connecting to the Network
(Multicast)

1. Mobile host
   - Control panel
   - GloMop app
   - GloMop
   - Control interface
   - Deliv. classes
   - TCP/UDP
   - Overlay IP
   - CBQ Agent
   - IR
   - RF

2. Base station / FA
   - Decapd
   - Care-of address
   - Control interface
   - Snoop
   - Overlay IP
   - CBQ
   - IR
   - RF

3. Home agent
   - Overlay IP
   - Ethernet

4. Mobility database
   - Subnet manager
   - Metering & Credit

Steps:
- Register;
- Join multicast group;
- Start forwarding;
- Care-of address

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Connecting to the Network
(Multicast)
Connecting to the Network
(Multicast)

mobile host

control panel  GloMop app  unmod app
GloMop control interface  deliv. classes  TCP/UDP
Overlay IP
CBQ Agent
IR  RF  ...

base station / FA

beacon  decapd
control interface  snoop
Overlay IP
CBQ
IR  RF  ...

home agent

Overlay IP
Ethernet

Mobility database
Subnet manager
Metering & Credit
registration

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Connecting to the Network
(Hybrid)

mobile host

registration request

foreign agent

care-of address update

home agent

base station

ICMP router advertisement

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Connecting to the Network (Hybrid)

- Mobile host
  - Control panel
  - GloMop app
  - Unmod app
  - Control interface
  - Deliv. classes
  - TCP/UDP
  - Overlay IP
  - CBQ Agent
  - IR
  - RF

- Foreign agent
  - Overlay IP
  - Ethernet
  - Ack
  - Mobile IP
  - Ethernet

- Home agent
  - Mobility database
  - Subnet manager
  - Metering & Credit

- Base station
  - Beacon
  - Decap
  - Control interface
  - Snoop
  - Overlay IP
  - CBQ
  - IR
  - RF
  - ...
Connecting to the Network (Hybrid)

mobile host

control panel
GloMop app
GloMop
control interface
deliv. classes
TCP/UDP
Overlay IP
CBQ Agent
IR RF . . .

foreign agent

Overlay IP
Ethernet

base station

beacon
decap
control interface
Overlay IP
CBQ
IR RF . . .
snoop

home agent

Mobile IP
Ethernet

Mobility database
Subnet manager
Metering & Credit

join multicast group; start forwarding

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Kerberos Authentication

- **centralized, secure database** (KDC) **holds secrets** (DES key) **only known by principles**
- **to access Kerberized services**, principles are issued **tickets** for those services by the ticket-granting server (TGS)
- a ticket for the ticket-granting server (TGT) **is issued** by the KDC
- the TGT is encrypted with the issuee’s secret
- **tickets contain session keys**
Authenticated Proxied Services

- proxies are treated as principles
- clients access proxies by gaining tickets for their services
- cross-domain authentication is possible by having a foreign TGS listed as a principle in the local system
- **Charon** is a protocol that enables Kerberos for impoverished clients
- **Charon** also enables “indirect authentication”
Charon Authentication: Obtaining TGT for Visited Proxy

- GloMop
  - DNS
    - find proxy request
    - proxy address

- Visited Proxy
  - Home TGT request

- Home Proxy
  - Home TGT request

- Home KDC
  - Home TGT request

- Visited KDC
  - Home TGT request

- Visited TGS
  - Home TGT request

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Charon Authentication: Obtaining TGT for Visited Proxy

GloMop → Visited Proxy
Visited TGT request

Visited Proxy → Home Proxy
Visited TGT request

Home Proxy → Visited TGT request

DNS

Visited TGS
Visited KDC

Home TGS
Home KDC
Charon Authentication: Obtaining Session Key with Visited Proxy

- GloMop
- Visited Proxy
  - Visited TGS
  - Visited KDC
- Home Proxy
  - Home TGS
  - Home KDC
- DNS

 Proxy ticket request
 Proxy ticket
 Proxy ticket request
Handoff from IR to WaveLAN
(load balancing)
Handoff from IR to WaveLAN
(load balancing)

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Handoff from IR to WaveLAN
(load balancing)

old base station

Overlay IP

control interface

snoop

Overlay IP

control interface

snoop

Subnet manager

Mobility database

Metering & Credit

load balance hint

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Extended Handoff Subroutine

Mobile host
- Control panel
- GloMop app
- GloMop
- Control interface
- Deliv. classes
- TCP/UDP
- Overlay IP
- CBQ Agent
- IR
- RF
- Old base station

New base station
- Control interface
- Snoop
- Overlay IP
- CBQ
- IR
- RF
- Old base station

Stop buffering; start forwarding

Foreign agent
Home agent
Mobility database
Subnet manager
Metering & Credit

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Extended Handoff Subroutine

Mobile host
- Control panel
- GloMop app
- GloMop app
- Control interface
- Delivery classes
- TCP/UDP
- Overlay IP
- CBQ Agent
- IR
- RF

New base station
- Beacon
- Decapd
- Control interface
- Snoop
- Overlay IP
- CBQ
- IR
- RF
- Multicast addr
- Ack
- Foreign agent
- New care-of address
- Home agent

Old base station
- Beacon
- Decapd
- Control interface
- Snoop
- Overlay IP
- CBQ
- IR
- RF

Subnet manager
- Mobility database
- Metering & Credit

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Extended Handoff Subroutine

mobile host
- control panel
- GloMop app
- Overlay IP
- CBQ Agent
- IR, RF

new base station
- control interface
- Overlay IP
- snoop
- CBQ
- IR, RF

old base station
- control interface
- Overlay IP
- snoop
- CBQ
- IR, RF

load balance, handoff prediction
- Foreign agent
- Home agent
- Mobility database
- Subnet manager
- Metering & Credit
- Deliv. classes
- TCP/UDP
- Unmod app
Handoff from WaveLAN to WaveLAN

(mobility)

buffering base station

forwarding base station

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Dynamic Adaptation via NCM

PTM

Distiller

mobile

proxy

unmod app

GloMop app

control panel

GloMop

TCP/UDP

overlay IP

cbq

IR

RF

... deliv. classes

control interface

net state!

HTTP

POP3

GloMop

Proxy

TCP/UDP

overlay IP

GloMop

Ethernet
PTM Load Balancing

PTM

Distiller

load
spawn
distiller?

mobile

proxy

unmod app
GloMop app
control panel

GloMop

TCP/UDP
deliv. classes
control interface
overlay IP
cbq
IR RF ...

HTTP
POP3
GloMop

Proxy

TCP/UDP
deliv. class
control interface
overlay IP
Ethernet
Delivery class abstractions

PTM

Distiller

mobile

unmod
app

TCP/UDP

overlay IP

cbq

IR

RF

...
Dynamic Link Allocation

Network Layer

Data Link Layer

Dynamic Allocation (Class-Based Queuing)

TCP Snoop

Overlay IP

Control Interface

beacon

decapd

Ethernet

RF

...
Handoff from WaveLAN to Metricom
(lost beacons)

new bs (non-cooperating)

mobile host

control panel
GloMop app
GloMop app
control interface
deliv. classes
TCP/UDP
Overlay IP
CBQ Agent
IR RF . . .

forwarding base station

beacon
decapd
control interface
Overlay IP
CBQ
IR RF . . .
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Flexible Refinement/QoS Mechanism

download time: 15 s

mobile

GloMop

TCP/UDP
deliv. classes
control interface
overlay IP
cbq
IR RF ...

PTM

Distiller

proxy

Proxy

HTTP POP3 GloMop

TCP/UDP
deliv class
control interface
overlay IP
Ethernet

GloMop

unmod app

more colour

more resolution

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Handoff from Metricom to WaveLAN

(change of domain)

mobile host

control panel
GloMop app
GloMop app
control interface
deliv. classes
TCP/UDP
Overlay IP
CBQ Agent
IR RF...

(new beacon)

(new beacon)

overlay

Overlay IP
CBQ
IR RF...

new base station

old bs (non-cooperating)

periodically retry lower interface

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Core Daedalus Architecture Summary

• Supports seamless roaming in heterogeneous and foreign environments
  – vertical and horizontal handoff support

• Custom Network Stack at MHs and (cooperating) BSs
  – unmodified corresponding hosts, home agents
  – compatibility with Mobile-IP

• Static assumptions about network characteristics

• Accepts handoff “hints” to handoff controller

• Some protocol-specific network optimization
  – TCP snoop
Extended Daedalus Architecture Summary

- **Adds custom network stack at proxy host**
  - delivery class abstraction for data-type specific transport

- **Dynamic allocation at data link (hop by hop)**

- **Extensible, independent network services model**
  - mechanisms facilitate localized policy decisions

- **Dynamic measurement and notification of changes in network characteristics (via NCM)**

- **Network performance enhancements**
  - low-latency handoff
  - hierarchical foreign agents
  - additional transport-layer optimizations
Core Proxy Architecture Summary

- **Unmodified apps, application-specific protocols**
  - proxy mechanism is either transparent to or already supported by the application
  - functionality and efficiency limited by the application’s protocol
- **On-the-fly distillation and refinement possible**
  - client and network adaptation, unmodified servers
  - proxy optimizations (prefetching, caching)
  - dynamic network adaptation is missing (no NCM)
- **Loose coupling with Daedalus stack**
Extended Proxy Architecture Summary

- **Pluggable proxy architecture**
  - support for both modified and unmodified apps
  - separation of load-balancing concerns into PTM

- **GloMop application support layer**
  - efficient custom protocol
  - explicit refinement and QoS mechanisms

- **Authenticated proxied services**

- **Tight coupling with Daedalus stack**
  - dynamic network adaptation via NCM
  - allow delivery policy through delivery classes
Some Open Issues

- **Elements of the service architecture**
  - complex element interaction and inter-dependency
  - the metering mechanism is not fully resolved

- **Multiple simultaneous network interfaces**
  - multiplexing of application data
  - undesirable for power-management

- **Link-layer state on handoff**
  - is state transfer necessary?
  - how to deliver data queued in base-station
  - different link-management policy in new network?

- **Network connection monitor**
  - stability and granularity of statistics
Some Open Issues (continued)

• **Function migration**
  – “Evil Twin” versus protocol filters at the proxy
  – can Rover-style migration coexist?

• **Time-constant for proxy-adaptation**
  – how quickly does it adapt, and to what granularity of network variation?
  – should the proxy receive adaptation hints?

• **User interface issues**
  – understanding and specifying constraints
  – data-type specific refinement controls
  – per-chunk, per-document, and per-session constraints