**NIMBLE:** Many-time, Many-where communication support for information systems in highly mobile and wireless environments

**New Ideas:**
- Infostations
  - Many-time, many-place communication paradigm
  - Spotty wide-band coverage for fast data transfer
  - Different types of Infostations
- Low Latency Protocols
  - Reservation protocols for Infostations
  - Adaptive content, rates for low-latency transfers
  - Caching, scheduling, transfer protocols
- Applications
  - Drive-by services
  - Spooled high-speed data transfers
  - Integrating low b/w network and infostations

**Impact:**
- A new architecture for providing wide-band coverage at specific places
- Opportunistic protocols for delivering rich data at peak rate to moving terminals
- Novel service models for delivering high data rate services tailored to different mobility patterns

**Schedule:**
- Designed WINMAC for Infostations
- Implement MAC protocols for Infostation Network
- Implement advanced rate switching and retransmission in WINMAC

- Jul 97
- Oct 97
- Oct 98
- Oct 99
- Jun 00
- Oct 00

- Implemented rate adaptation algorithms for high speed terminals
- Developed opportunistic protocols for different models of Infostations (Prototypes I and II)
- Server design for low-latency data transfers to Infostation terminals
- Integrated demo of services over multiple networks (Infostations and low b/w network)

Rutgers University: B. R. Badrinath, Richard Frenkel, David Goodman, Tomasz Imielinski
NIMBLE significant recent accomplishments

• Infostations MAC: *Rate adaptation at the MAC layer*  Q499
  - *Rate adaptation in the MAC for high velocity mobile terminals* (tested 30 mph, goal 60 mph)
    • Mobile dynamically selects best available data rate using real-time channel measurements.
    • **Low rate: 250 kbps, Medium rate: 500 kbps, High rate 2 Mbps**
      - Significant throughput improvement in a fading (mobile) environment.
      - Allows for fringe area low bandwidth communication to overcome backbone latencies.

• Infostations MAC: Adaptive link layer retransmission.  Q3 99
  - Adaptive redundant retransmission based on error in the channel
  - Threshold based retransmission: dynamically decides number of retransmissions

• Optimal file caching algorithm for an Infostation network.  Q2 99

• Radio-API Simulator  Q1 99
  - Testing of WINMAC blocks in a simulated environment
  - Evaluated WINMAC components
Infostation Coverage Pattern

Infostation coverage pattern:
High data rate service is available only near the infostation. Majority of data transfer occurs at the center of the cell. Low data rate ring is used to register and initiate a data transfer. Need fast rate switching and adaptive retransmission schemes.
Rate Switching

- Mobile dynamically adjusts the rate
  - *This is decided based on channel quality*
  - *Channel quality is determined based on the number of beacons received and their type*
- If sufficient high rate beacons are received then the mobile switches to a higher rate
- Three rates implemented: 250 Kbps, 500 Kbps and 2 Mbps
Beacons are sent at three different data rates.

Based on the channel conditions the mobile receives one or more of these beacons.

Based on what is received the mobile makes a decision to stay at the given rate or switch to higher (lower) rate based on the beacon counters.

\[ H = 2 \text{ Mbps}, \ M = 500 \text{ Kbps}, \ L = 250 \text{ Kbps} \]
Adaptive Retransmission

1. Divide IP packet into $N_{\text{frag}}$ fragments
2. Transmit all the fragments of the IP packet
3. Retransmit the fragments in error
4. If $\gamma > \alpha$, stop retransmission
5. If $\gamma > \beta$, send I-copies
6. Send J-copies
IP throughput improvement

IP throughput (kbps/lot) vs. Probability of a physical packet error

- No Retransmission at Link Layer
- Basic Scheme: α = β = 1; i = j = 1
- The proposed scheme: α = 0.5, β = 0.25, i = 5, j = 3
IP packet drop probability

![Graph showing IP packet drop probability vs. Average PER for different schemes. The graph includes lines for Basic Scheme, Multicopy Scheme, and The proposed scheme.]
Reduction in retransmitted fragments

Adaptive redundant retransmission improves IP goodput.
Prototype Services

Download /upload huge files from multiple infostations

Completing atomic transfers for MIME content (e-mail with attachments, CD quality audio (teaming with Daimler-Chrysler))
NIMBLE FY00 Plans

• Development of WINMAC For Infostations: 1Q/2Q00
  - Test and verify advanced rate switching scheme 1Q00
  - Complete implementation of adaptive retransmission scheme 2Q00

• Service architecture for Infostation prototypes 2Q00
  - Complete Infostation server design and deploy 2Q00
  - Complete Infostation client design for various applications 2Q00

• Build and demo Infostation prototype II 3Q/4Q00

• Integrated demo plans (Final GloMo Demonstration)
  - Build and demo services using Infostations prototype II
  - Show reconciliation of a distributed database via Infostations. Show atomic transfer of data via an Infostations network 4Q00
Possible plan for final demo

1. Warfighters gather troop position data on handheld terminal.

2. Upon approaching infostation, new data is automatically uploaded at high speed and database is reconciled.

3. Mobile users traveling in vicinity of infostation automatically receive updated copy of database in a high speed download.
I. Infostation architecture R&D
• Develop Service Architecture for InfoStation network
• Distributed Data Caching for InfoStation Cluster
• Service Deployment over InfoStation Network

II. Adaptive Protocol R&D
• WINMac development for InfoStations
• Integration of InfoStations with other types of Networks (IP, PSTN)
• End-to-End protocols for content delivery

III. Integrated system demos
• InfoStation Prototype I
• InfoStation Prototype II
• Location dependent service
• Integrated demo using InfoStation prototype II

<table>
<thead>
<tr>
<th>Tasks</th>
<th>FY97</th>
<th>FY98</th>
<th>FY99</th>
<th>FY00</th>
<th>FY01</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Infostation architecture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>R&amp;D</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>• Develop Service Architecture for InfoStation network</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>• Distributed Data Caching for InfoStation Cluster</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>• Service Deployment over InfoStation Network</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>II. Adaptive Protocol R&amp;D</td>
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<td></td>
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<td>• WINMac development for InfoStations</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>• Integration of InfoStations with other types of Networks (IP, PSTN)</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>• End-to-End protocols for content delivery</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
</tr>
</tbody>
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Rutgers NIMBLE - Schedule
### FY99

7. Complete radio network drivers  | Rutgers | 4Q98 | Completed
8. Demonstrate “Post-It” Service via InfoStation  | Rutgers | 4Q98 | Completed
9. Design rate adaptation schemes for mobile nodes  | Rutgers | 3Q99 | Completed
10. Implement WINMac emulator for optimization  | Rutgers | 1Q99 | Completed
11. Complete Implementation of reservation scheme for mobile networks  | Rutgers | 2Q99 | On Schedule

### FY00

13. Design of control and data channel for InfoStation Prototype II  | Rutgers | 4Q99 | Completed
14. Simulate performance of real-time services for mobile networks  | Rutgers | 4Q99 | Completed
15. Advanced rate switching  | Rutgers | 1Q00 | On Schedule
16. Retransmission schemes  | Rutgers | 2Q00 | On Schedule
17. Infostation Server design and deployment  | Rutgers | 2Q00 | On Schedule
18. Infostation client design and deployment  | Rutgers | 2Q00 | On Schedule
19. Demonstrate information services with prototypes I and II  | Rutgers | 3Q00 | On Schedule
20. Integrated demo using InfoStation Prototype II  | Rutgers | 4Q00 | On Schedule