Efficiently Managing Location Information with Privacy Requirements in Wi-Fi Networks: a Middleware Approach

Paolo Bellavista
Antonio Corradi
Carlo Giannelli

DEIS, University of Bologna,
V.le Risorgimento n.2, 40136 Bologna Italy
{pbellavista, acorradi, cgiannelli}@deis.unibo.it
User privacy in Location Based Services
  - location information management

Middleware for privacy-enabled LBS with network traffic concern:
  - request dropping
  - location obfuscation

Experimental Results
Location Based Services

- Mobile devices + Wireless technologies ➔ Positioning systems (without additional hardware)

- Location Based Services (LBSs)
  - virtual museum assistance
  - service discovery

- Location information
  - symbolic model with variable granularity

<table>
<thead>
<tr>
<th>Location ID</th>
<th>Location Information</th>
<th>Granularity</th>
</tr>
</thead>
<tbody>
<tr>
<td>l1</td>
<td>Italy, Tuscany, Siena</td>
<td>3</td>
</tr>
<tr>
<td>l2</td>
<td>Italy, Emilia, Bologna, EngFaculty</td>
<td>4</td>
</tr>
</tbody>
</table>
User privacy issue

- User privacy is a primary issue:
  - location disclosure – user privacy
  - location information disclosed only when needed and only at the proper detail level (granularity)

- When sending information to LBS?
- Which information to LBS?
  - user privacy/LBS requirements
Divulgate location and request services only when needed

- client requests services at each location change: more services than needed
- client performs request dropping

<table>
<thead>
<tr>
<th>Location ID</th>
<th>Location Information</th>
<th>Granularity</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Italy, Emilia, Bologna, EngFaculty, Lab2, PhDZone</td>
<td>6</td>
</tr>
<tr>
<td>12</td>
<td>Italy, Emilia, Bologna, EngFaculty, Lab2, Office</td>
<td>6</td>
</tr>
<tr>
<td>13</td>
<td>Italy, Emilia, Bologna, EngFaculty, Lab2</td>
<td>5</td>
</tr>
</tbody>
</table>
Location information obfuscation:
- client discloses location information tacking into consideration user privacy requirement

Service filtering
- LBS provides information about managed locations
- location obfuscation implies more descriptions at each service request
- LBS response filtering

<table>
<thead>
<tr>
<th>Location ID</th>
<th>Location Information</th>
<th>Granularity</th>
</tr>
</thead>
<tbody>
<tr>
<td>l1</td>
<td>Italy, Emilia, Bologna, EngFaculty, Lab2</td>
<td>5</td>
</tr>
<tr>
<td>l2</td>
<td>Italy, Emilia, Bologna, EngFaculty, CommLab</td>
<td>5</td>
</tr>
<tr>
<td>l3</td>
<td>Italy, Emilia, Bologna, EngFaculty</td>
<td>4</td>
</tr>
</tbody>
</table>
Proposed solution performs
  - request dropping
  - location obfuscation
  - service filtering

Two-level proxy-based middleware
  - no changes to application client and LBS
  - no additional computation on MN
  - a proxy on behalf of MN, a proxy on behalf of LBS
Middleware architecture

- **CProxy**
  - close to the currently associated AP
  - knows user privacy requirement
  - performs request dropping
  - migrates to follow MN

- **SProxy**
  - close to LBS
  - knows LBS location granularity requirement
  - hides to LBS CProxy/MN identity: user anonymity

- CProxy and SProxy share LBS and user requirements
- Either CProxy or SProxy performs location obfuscation to satisfy LBS/user privacy requirements
Working modes (1)

- PrivacyOff
  - middleware not exploited
  - no location obfuscation for user privacy requirements ➔ no service filtering needed
  - request dropping unavailable

- Anonymous
  - middleware exploited
  - request dropping
SSPM: Server Side Privacy Management
- SProxy performs location obfuscation and service filtering
- service filtering close to LBS

CSPM: Client Side Privacy Management
- as SSPM but CProxy in charge of location obfuscation and service filtering
### Cumulative Service Time (CST):
- sum of service response times in the current and already visited locations
- underlines middleware performance in a typical LBS scenario with multiple client requests

<table>
<thead>
<tr>
<th>Location ID</th>
<th>Location Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Italy, Emilia, Bologna, EngFaculty, Lab2, PhDZone</td>
</tr>
<tr>
<td>12</td>
<td>Italy, Emilia, Bologna, EngFaculty, Lab2, Office</td>
</tr>
<tr>
<td>13</td>
<td>Italy, Emilia, Bologna, EngFaculty, Lab2, StudZone</td>
</tr>
<tr>
<td>14</td>
<td>Italy, Emilia, Bologna, EngFaculty, CommLab, BTStation</td>
</tr>
<tr>
<td>15</td>
<td>Italy, Emilia, Bologna, EngFaculty, CommLab, Admin</td>
</tr>
<tr>
<td>16</td>
<td>Italy, Emilia, Bologna, MathFaculty, Floor1, Room12</td>
</tr>
<tr>
<td>17</td>
<td>Italy, Emilia, Bologna, MathFaculty, Floor1, Room5</td>
</tr>
</tbody>
</table>

- Location information granularity greater than LBS one
Experimental results

- **PrivacyOff**
  - CST grows linearly
- **Anonymous**
  - l1, l4, l6 great service delay
  - l2, l3, l5, l7 request dropping
- **SSPM**
  - Service filtering on the server-side
- **CSPM**
  - Service filtering on the client-side
  - worse performance, greater user privacy
A middleware solution for privacy-enabled LBS simplifies the design and implementation of more user-trusted LBSs.

A two-level proxy-based architecture to provide:
- user anonymity
- user privacy
- limited traffic overhead

Proposed middleware performance comparable with a simpler privacy-unaware C/S solution.

CProxy/SProxy not just for request dropping and location obfuscation:
- SProxy caches requests for multiple clients
- CProxy caches for multiple requests from the same client
Acknowledgements

- Work supported by MIUR FIRB WEBMINDS and CNR Strategic IS-MANET Projects