### Title
Real-Time Mobile Applications in Intermittently Connected Networks

### Authors
Hansen/Jeffery

### Report Date
28 OCT 2014

### Institute
Software Engineering Institute Carnegie Mellon University
Pittsburgh, PA 15213

### Summary
The original document contains color images.

### Distribution/Availability Statement
Approved for public release, distribution unlimited.

### Security Classification
- Report: Unclassified
- Abstract: Unclassified
- This Page: Unclassified

### Number of Pages
11

### Notes
Sending comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.
Overview

Problem

• Real-time distributed applications depend on reliable communications.
• Tactical environments are often characterized by disconnected, intermittent and low-bandwidth (DIL) communications.

To address this problem, we developed methods that

• Enable real-time shared group context in a DIL environment.
• Keep information synchronized in real time despite communication outages.
• Apply group context to make these more effective.
Approach: Keep network users productive

Our approach is to consider three communication states:

- **Connected**
- **Disconnected**
- **Reconnecting**

<table>
<thead>
<tr>
<th>Maintain shared group context</th>
<th>Applications continue to function</th>
<th>Re-establish shared group context as quickly and accurately as possible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make best use of available bandwidth</td>
<td>Predict state where possible</td>
<td></td>
</tr>
<tr>
<td>Pre-cache data likely to be relevant later in the mission</td>
<td>Predict location of teams based on mission plan</td>
<td>Prioritize synchronization of critical messages</td>
</tr>
<tr>
<td>Delay transmission of noncritical data</td>
<td>Provide connectivity map to help the user reconnect</td>
<td>Eliminate redundant messages</td>
</tr>
</tbody>
</table>
Implementation

ISE (Information Superiority to the Edge)
- Group-context aware middleware
- Wireless data synchronization

ISE+ (Enhanced Version)
- DTN (Delay Tolerant Networking) bundle protocol used for message delivery
  - Modified open-source implementation
- DTN Metadata Extension Blocks
  - Filtering of irrelevant or obsolete data
  - Prioritization of messages
- SA prediction for disconnected operation
- Dynamic connectivity map construction
- Pre-caching of mission-relevant data

ISE Core
ISE+ SA Prediction
SEI-JDTN with metadata extension
Metadata Supports Forwarding Decisions

Use DTN metadata extension block to attach key-value pairs to bundles

- Time and location
- Priority
- Type of payload (image, voice, video, text, …)
- Set of tags describing the payload content (selected from a mission-specific tag set configured in ISE)
  - E.g., building, crowd, fire, protest, injured person, etc.

DTN nodes are configured with scheduling and discard policies to

- Determine the priority order in which to forward bundles, some bundles may not be forwarded at all but held back until the end of the mission
- Detect duplicate bundles that should be de-prioritized or discarded
- Decide which bundles to delete in case the node runs out of memory
Metadata Experiments

Goal: Show reduction in transmission of redundant messages and reconnection time after a disconnection.

Generate ISE messages of varying types

- Location Updates (expire)
- Comment added to event (data replacement)
- Multiple photos of same target (redundancy elimination)
- Important but not mission relevant (conditional delivery)

Independent Variables:
- Metadata extensions: disabled, enabled
- Disconnect time (sec.): 10, 20, 30, 40, 50
- Messages per second: 5, 10, 20
Message Reduction with Metadata

20% Reduction in messages sent
Reconnect Time with Metadata

70% Reduction in reconnect time

- nometa-20
- nometa-10
- nometa-5
- meta-20
- meta-10
- meta-5

Time to Reconnect (msec) vs. Disconnect Time (sec)
Impact

Improve operational capabilities for soldiers/first responders in DIL environments

- Ability to operate without fully connected network.
- Faster and lower energy synchronization of most relevant mission data.
- Increased mission time capability.

Stakeholders include

- Mitre, USMC (TID and CIO reps), DHS First Responder’s Group, SOCOM S&T

Demonstrated effectiveness of metadata enhancements

- 20% reduction in traffic load after disruption.
- 70% reduction in time to reestablish group context after disruptions.

Incorporated DTN technologies into ISE

- ISE to continue with DTN enhancements in FY15 EETS project
## Contact Information Slide Format

**Presenter / Point of Contact**
Jeffery Hansen, SSD  
Telephone: +1 412-268-9565  
Email: jhansen@sei.cmu.edu

**U.S. Mail**
Software Engineering Institute  
Customer Relations  
4500 Fifth Avenue  
Pittsburgh, PA 15213-2612  
USA

**Web**
www.sei.cmu.edu  
www.sei.cmu.edu/contact.cfm

**Customer Relations**
Email: info@sei.cmu.edu  
Telephone: +1 412-268-5800  
SEI Phone: +1 412-268-5800  
SEI Fax: +1 412-268-6257