Exploiting the Short Message Service as a Control Channel in Challenged Network Environments

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Outline

1. Introduction
   - Motivation
   - Objectives
2. Understanding SMS
   - Characteristics
   - Testbed
   - Analysis
3. Design
   - Protocol
   - Architecture
   - Implementation
4. Conclusions

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Take home points

- Cellular network is highly erratic under bursty workloads.
- Characterized properties of the SMS network using bursty workloads using a variety of commondity hardware.
- Designed and built a robust data channel on top of SMS.

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Motivation

Growth of SMS

- Cellular networks are ubiquitous.
- Over 1 trillion SMS message sent in 2005.
- Projected to be 3.7 trillion SMS messages per year by 2012.
- Competition between carriers, growth of MMS, and data services are driving down prices*.
  - (India) smsjunction.com : Rs. 0.09 ($0.002 USD) / message
  - (India) znisms.com : Rs. 0.28 ($0.006 USD) / message
  - (US) AT&T : unlimited SMS messages for $5 USD / month

* Except in Canada: no unlimited plans and charges for incoming messages.

Applications of SMS

Existing applications

- Messaging, e-voting/surveys, Internet search, e-commerce, system monitoring, notifications, etc.
  - Nearly always constrained to a single SMS message.

Can SMS be used to transport much larger quantities of data?

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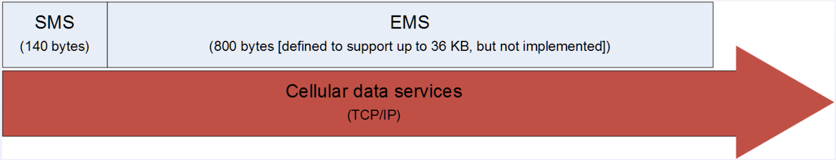
Existing solutions

- Enhanced Message Service (EMS)
  - Application layer extension to SMS.
  - Device support is poor.
- Cellular data services (GPRS/EDGE, EVDO)
  - Greatly superior as a data service.
  - Often two orders of magnitude cheaper.
  - Sparsely deployed in developing regions.
  - Mobile end-points often not reachable.



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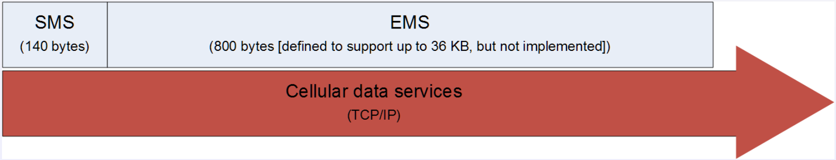

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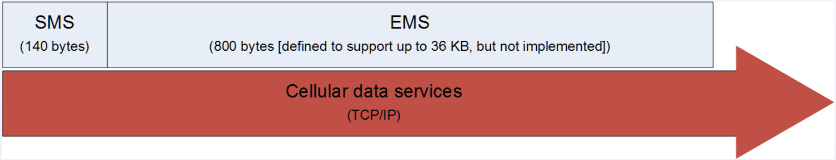

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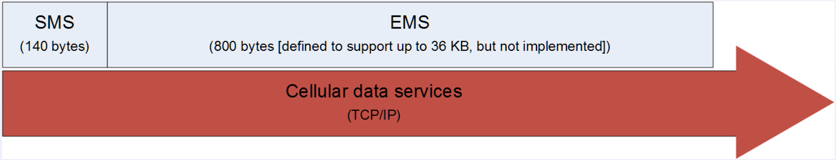

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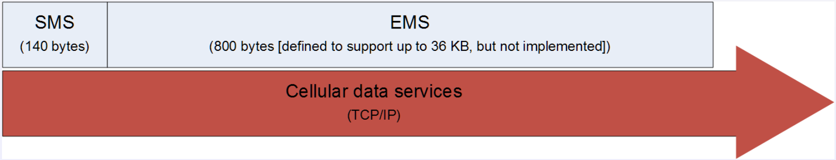

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Such as:

- Exchanging cryptographic keys.
- DTN routing table updates.
- Synchronous user creation at rural kiosks.
- And many more ...

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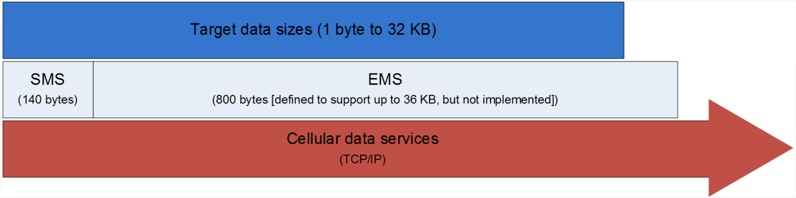
Goal

To build a general purposed data channel on top of SMS.



Objectives

- Fully utilize the capacity of the SMS network.
- Minimize monetary cost by reducing redundant messages.
- Reliable and robust to errors in hardware and the network.
- Must run on (or work with) a wide range of devices.
  - From current smartphones to previous generation/recycled cell phones.
- Compact and integrate seamlessly with existing mobile systems.

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How does the SMS network behave?

Previous work

- Examined traces of 59 million messages exchanged in India over a 3 week period. (Zerfos et al.)
- Trace covered approximately 10% of India's mobile subscribers (at the time).
- Examines SMS from a macro perspective.
- Does not examine mass message senders as an isolated group.

- We need to examine the SMS network from a micro perspective.
  - Focus on traffic patterns that differ significantly from normal human generated traffic.

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Understanding the characteristics of SMS

- Transmission rate
  - Signal strength
  - Medium contention
  - Communication latency with the device circuitry.
- Delay
  - Propagation delay
  - Queuing delays throughout the network
  - Transmission delay
  - Network may throttle or artificially delay messages.
- Loss rate
  - Transmission failure
  - Network congestion
  - Data corruption
  - Message may also expire if the receiver is not available.
- Other properties: transmission failure rate and reordering

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- Day of week (ex. Saturday night more congested than Tuesday morning).
- Time of day.
- Number of successive messages sent.
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Characterizing SMS

Testbed

- Two testbed configurations that represent common usage scenarios:
  - Messages exchanged between cell phones tethered to commodity PCs.
  - Messages exchanged between smartphones.

Testbed

Tethered cell phones

- Recycled Nokia cell phones connected over USB.
- Gammu used to communicate with Nokia phones over FBUS protocol.
- Tests controlled over LAN control channel.
- Time synchronized to the university's NTP server.
- Test consists of exchanging bursts of 10 messages per hour, 24 hours per day, over a 7 day period.
- Hourly success/failure notifications sent via email.
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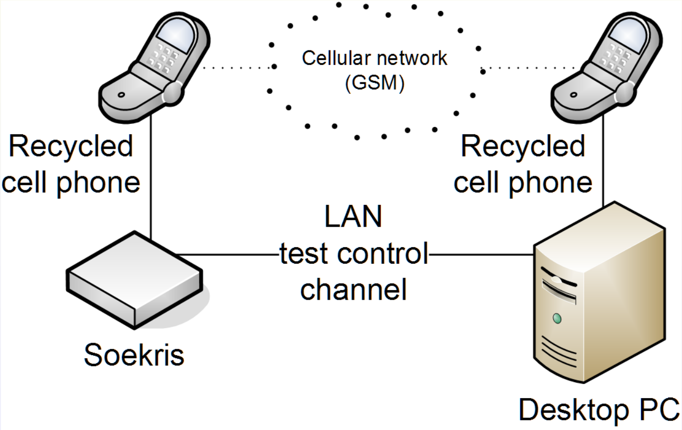
Cellular network
(GSM)
Recycled
cell phone
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Testbed

Drawbacks of using tethered cell phones

- Polling delays
  - Sending: messages copied to phone's "outbox", Gammu polls to verify that message is sent.
  - Receiving: Gammu polls phone's "inbox" to retrieve messages.
- Unstable hardware
  - Communication with phone frequently broken.
  - Software resets required.
- Cell phone is a black box.

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Smartphones

- Embedded environment created tighter integration between test driver and radio.
- Remove polling delays by using event driven APIs.
- Correlate signal strength, base station hopping with SMS measurements.
- Stable and reliable testbed (no hardware crashes, resets, etc.)

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Test setup

- Unidirectional and bidirectional transmission.
- Devices time synchronized to the GSM cellular network.
- Exchanges bursts of 10,20,40,80 messages between devices.
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Analysis

Summary

- Exchanged over 2400 SMS messages between devices.
- 98.5% transmission success rate.
- Contrary to expectations, the day of the week, time of the day, and burst size had no effect on results.

Analysis (continued)

Transmission rate

- Highly consistent for unidirectional traffic.
  - Mean: 4.03 sec (smartphone), 5.59 sec (cell phone)
- Bidirectional traffic has a significant effect.
  - Mean: 9.59 sec (smartphone)
  - ALOHA delays on shared random access channel.

Configuration	Mean	Minimum	Maximum	Median	Std. dev.
Tethered cell phone	5.59	4.19	29.23	5.63	0.76
Smartphone	4.03	2.98	39.36	3.34	3.81
Smartphone (bidirectional)	9.59	2.24	67.90	3.41	14.10

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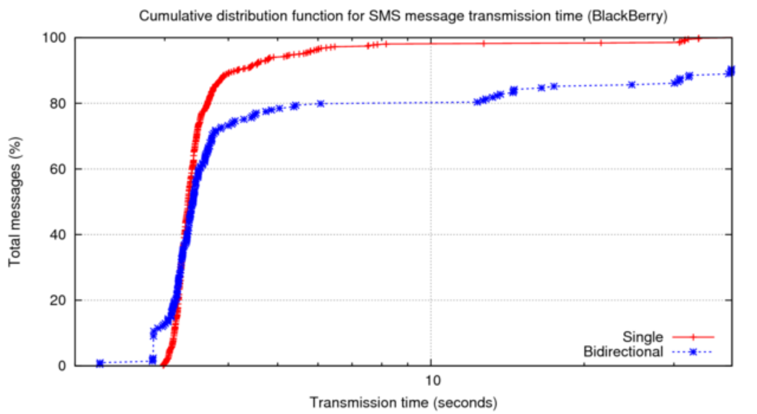

Analysis (continued)

Loss

- Loss rate was consistently less than 4%.
- Message duplication
  - Cell phone: 3.1%
    - Duplicates caused by communication failures with phone.
    - FBUS protocol frequently enters an inconsistent state.
  - Smartphone: 0.8%
    - Message duplication almost always the result of a drop in signal and cell tower change.

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Reordering

- Reordering is highly dependent on device.
  - Cell phone: 2.53%
  - Unidirectional smartphone: 31.72%
  - Bidirectional smartphone: 41.95%
- Message reordering almost always the result of a cell tower change.
  - (BlackBerry is unusually sensitive to decreased signal strength)

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- Highly variable (high standard deviation).
- Dependent on the hardware used.
- Bidirectional traffic had a significant impact on delay.
  - Channel contention at the edges of the network.

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Tethered cell phone	289.31	3.19	14534.32	14.00	1247.83
Smartphone	52.22	0.616	388.87	9.66	72.25
Smartphone (bidirectional)	203.02	1.98	645.56	173.44	174.19

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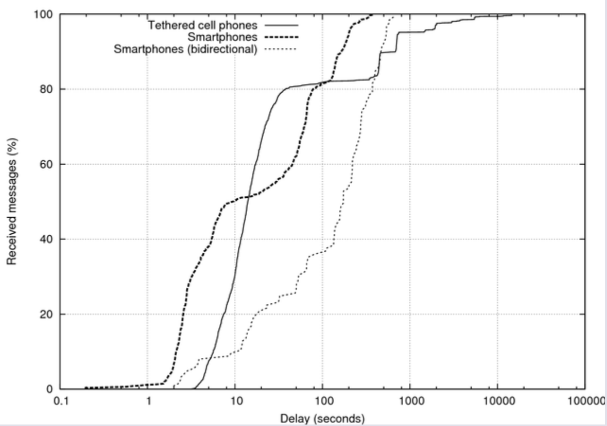

Analysis (continued)

The effect of delay

- Given a relatively consistent transmission time (with no delay between message transmissions), message have a high inter-arrival time.

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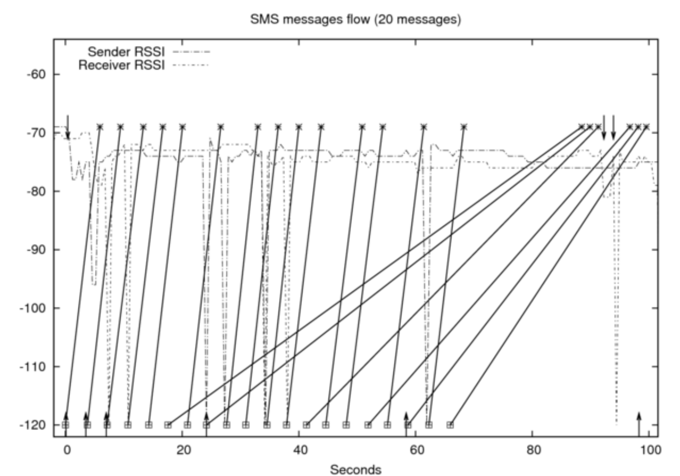
Tethered cell phone	67.32	0.0	14511.02	1.68	591.84
Smartphone	8.51	0.28	92.90	3.51	16.91
Smartphone (bidirectional)	28.14	2.90	274.08	5.59	39.97

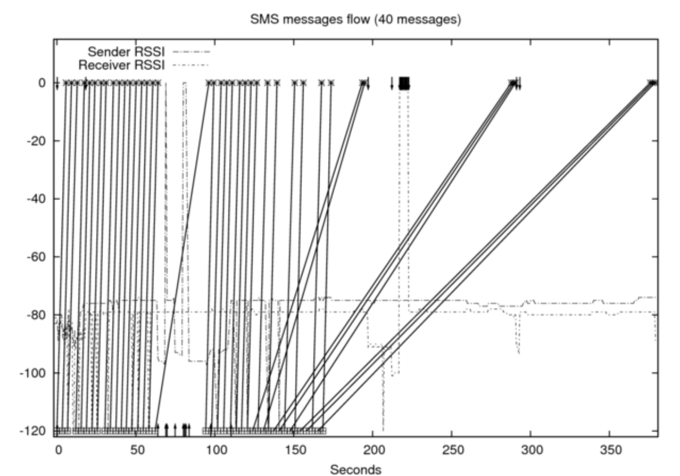
Example message flow

Unidirectional, 20 messages



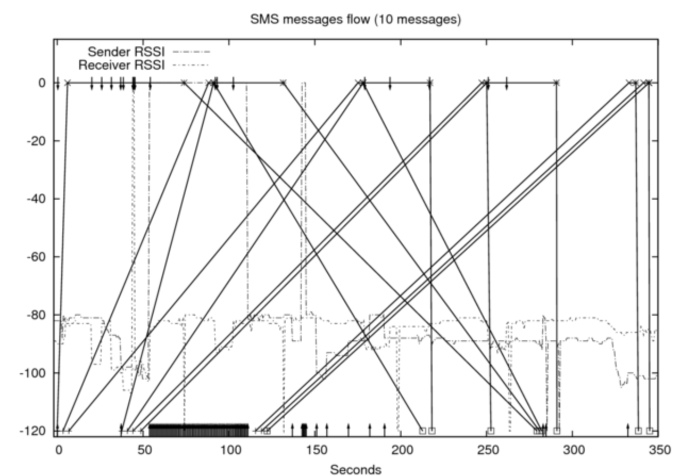
Example message flow

Unidirectional, 40 messages



Example message flow

Bidirectional, 10 messages



Design

Motivating criteria

- NIC dependency - the choice of hardware impacts the behaviour of SMS.
- Bidirectional traffic - significantly increases transmission time, delay, and reordering.
- Low loss rate - messages are rarely lost.
- Variable inter-message arrival times.
- Burst size has no effect - we can send as fast as possible.
- Messages remain intact.

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Protocol

Message format

- Message headers range from 2 - 3 bytes in length.
  - Maximize the fixed 140 byte message payload.
  - Details are in the paper.
- Base 64 mode to support
  - Reduces effective payload to 120 bytes.
  - Supports communication with a wide range of devices (that only accept printable ASCII characters).
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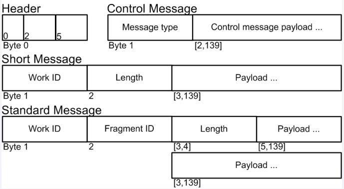

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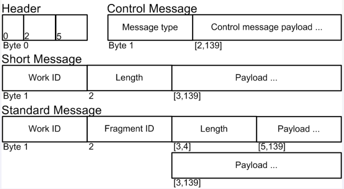

Protocol (continued)

Flow control and error control

- Experimented with SMART and sliding window flow control.
- NETBLT

Advantages of NETBLT

- Sender may transmit a continuous series of messages since burst size has no effect on transmission rate, delay, or loss.
- Bidirectional traffic is minimized through the use of a cumulative ack.
- Cumulative selective ack is tolerant to message reordering, random losses, and variable inter-arrival times.
- Low SMS loss rate requires few acks to be sent.

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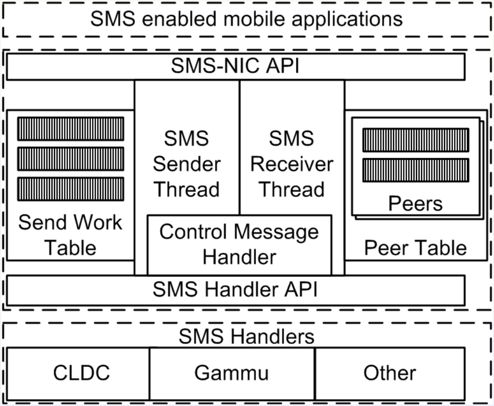
- Extensible architecture that allows for integration into existing mobile systems.
- Device *plug-ins* supported provided through *SMS Handler* API.
- Detailed architectural description in the paper.



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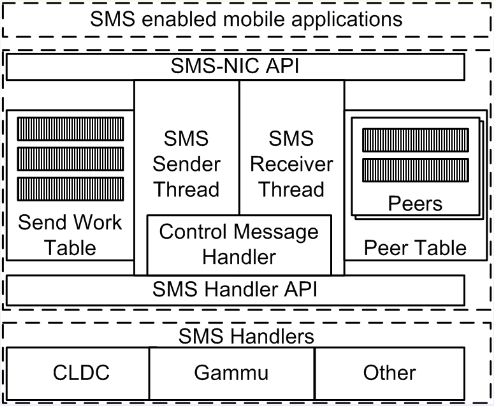

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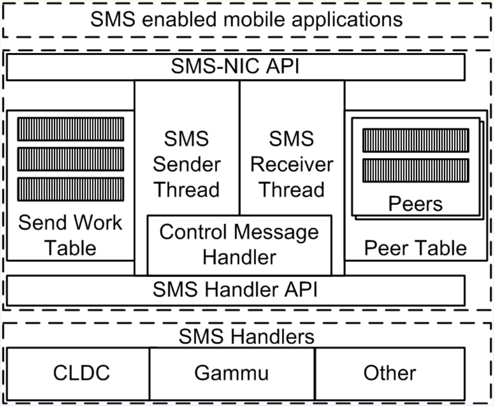

Implementation and evaluation

Summary

- The *SMS-NIC* is implemented in Java Micro Edition.
- CLDC compliant.
- Runs on WIDE range of existing mobile cell phones and smartphones.

Sample workloads

	GPS position (1 msg)	2 KB RSA key (16 msgs)	4 KB BLOB (31 msgs)
SMS-NIC	37.32 sec	97.23 sec	212.11 sec

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Summary of work

- Characterized the behaviour of SMS under continuous, bursty workloads.
- Designed and implemented a reliable and robust data channel built on top of SMS.
- Through an extensible architecture the SMS-NIC runs on or works with a wide range of mobile devices.

Using the SMS-NIC

Available for download

- SMS-NIC source code and measurement scripts available at: *http://blizzard.cs.uwaterloo.ca/eaoliver/sms/*
- Includes plug-ins for CLDC enabled devices and Gammu.
- Apache open source license.

Current user

- KioskNet *http://blizzard.cs.uwaterloo.ca/kiosknet/*
- Nearby Friend *http://crysp.uwaterloo.ca/software/nearbyfriend/*
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