

FoneAstra: Enabling Remote Monitoring of Vaccine Cold-Chains Using Commodity Mobile Phones

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Motivation

- Vaccine “Cold-Chain”: Temperature-controlled supply-chain for vaccine distribution
- 2°C – 8°C temperature range (WHO standard)
- Cold-chain problems can damage vaccines
 - Power failures, equipment failures etc.
- Freezing exposure more frequent and serious
- Need for continuous monitoring

Vaccine Cold-Chain (VCC) Monitoring

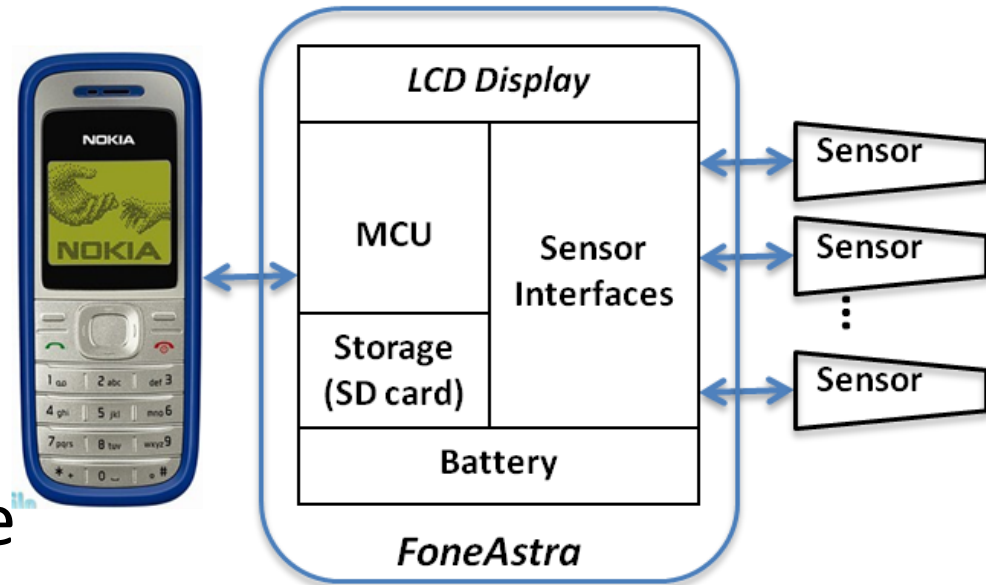


- Vaccine storage equipment at a health clinic in Nicaragua

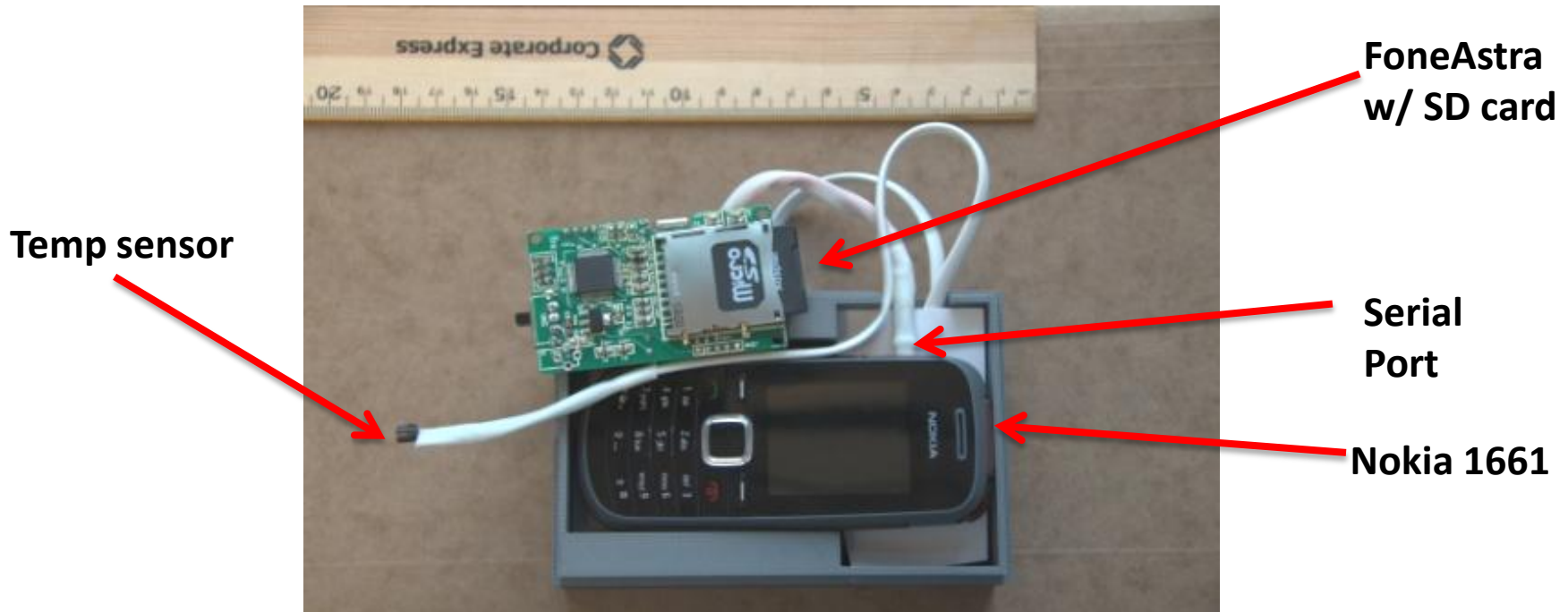
- FridgeTag devices record 30-day history
 - Daily max/min, alarms
- Paper-based temperature reporting
 - recorded twice daily

Networked Sensing Platform

- ARM7 MCU connected to low-tier phone
- Application hosted on MCU
- Sensing via I/O ports
- Phone as modem
 - Send/receive SMS
- Cell tower-ID from phone for location tracking
- Memory card for storage
- *Optional LCD for display*



FoneAstra (FA) for VCC Monitoring




- FA with temp sensor monitors equipment
- Temperature reports, alarms sent to server via SMS
- System cost: ~\$50 (includes mobile phone, FA, 1 sensor)
 - Significantly lower price due to low-tier cell phone
 - Lowers barrier for large-scale deployments
 - **Commercial products > \$500!**

FoneAstra Server

Log out erida

FONEASTRA

inveneo PATH 

Devices Watchers Preferences Message Log Reporters and Groups Messaging Message Tester FoneAstra

Registered FoneAstra Devices

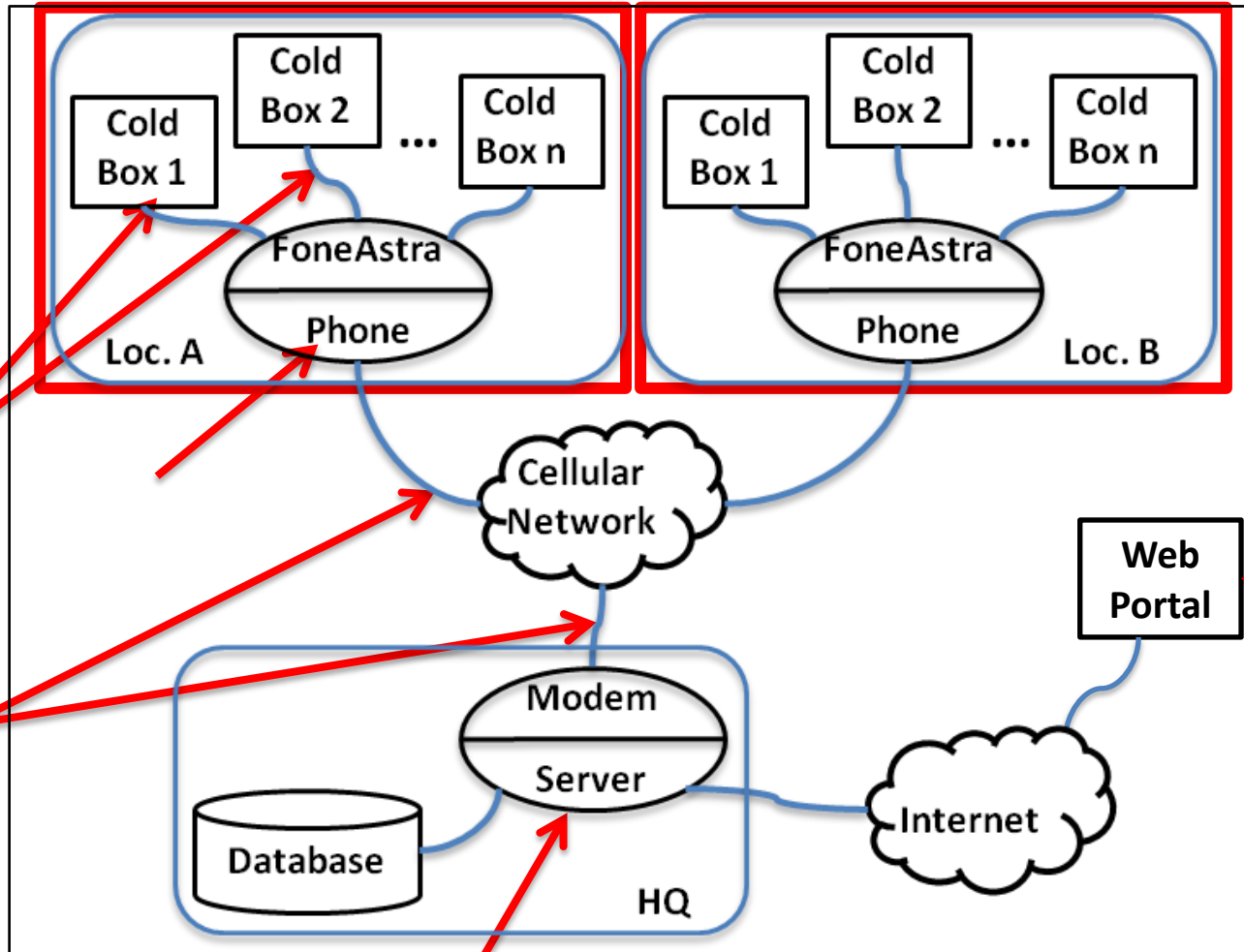
Name	IMEI	Alert Status	Configured?	Current Temp.	Last Report
FoneAstra HC Kamez	2441	✓	✓	4° C	2010-12-09 16:30:25
FoneAstra HC no 9	2449	✓	✓	7° C	2010-12-09 17:10:15
FoneAstra HC Qesarake	3	✓	✓	6° C	2010-12-09 16:21:21
FoneAstra IPH 1	2447	✓	✓	5° C	2010-12-09 16:53:39
FoneAstra IPH 2	2448	✓	✓	5° C	2010-12-09 16:58:29
FoneAstra Tirana DPH	2445	✓	✓	3° C	2010-12-09 16:48:42

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RapidSMS is available under [the BSD license](#).

- Linux-based netbook
- GSM modem for cellular connectivity
- Application framework based on RapidSMS/Django
- MySQL database
- Processes, stores and displays data received from FAs
- System cost: ~\$500 (includes netbook & GSM modem)

Deployment Block Diagram



Temperature sensors

SMS reports & alarms

Modes of Use

- Tightly coupled with phone
 - Configuration in current deployments
 - Powered by phone's battery
 - ~2 weeks of battery-life
- Loosely coupled with phone
 - Dedicated battery for FA
 - ~2 months of battery-life (standard Li-ion battery)
- Remotely configurable parameters
 - Sampling frequency
 - Reporting frequency
 - On-demand reporting

In-Lab System Setup

Temperature probe
going inside cold-box

- FA integrated with cold-box
- Periodically query sensor
 - Aggregate data over time
 - Routine SMS reports to server with aggregated data
 - 70 readings max (2 chars each)
- SMS alarms notify deviation
 - Server notifies “watchers”
- Server stores and displays temperature history
- Current temp queries over SMS



VCC Monitoring Trials

- Health post in Nicaragua (Aug 2010 – Sep 2010)
- On-going trial in Albania (Nov 2010 – present)



Albania Summary



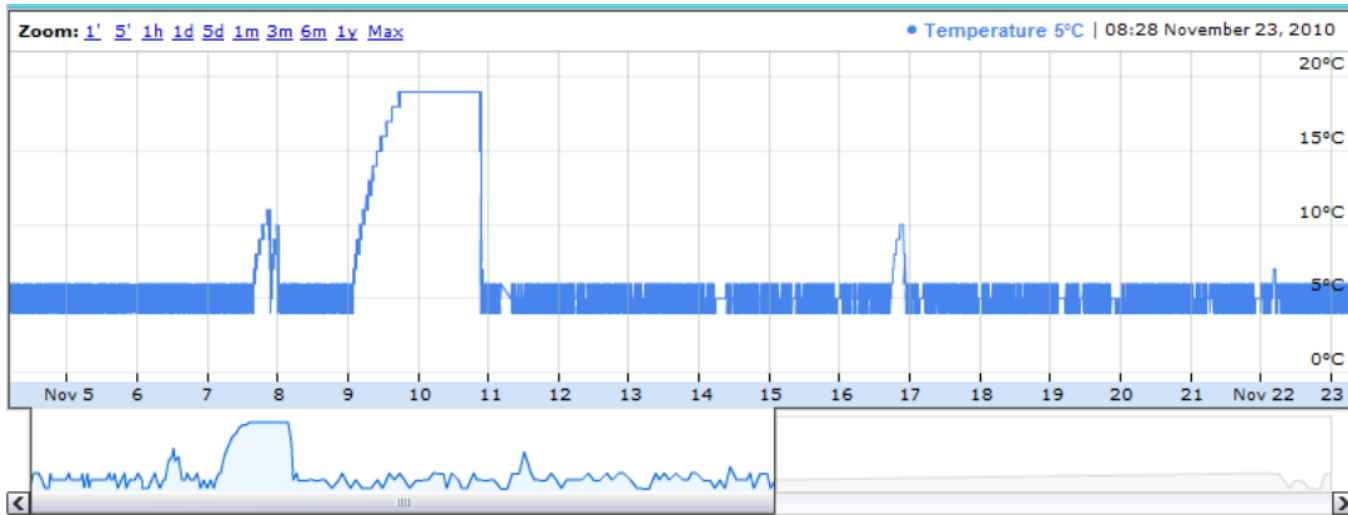
**FA installed at a health center
in Tirana**



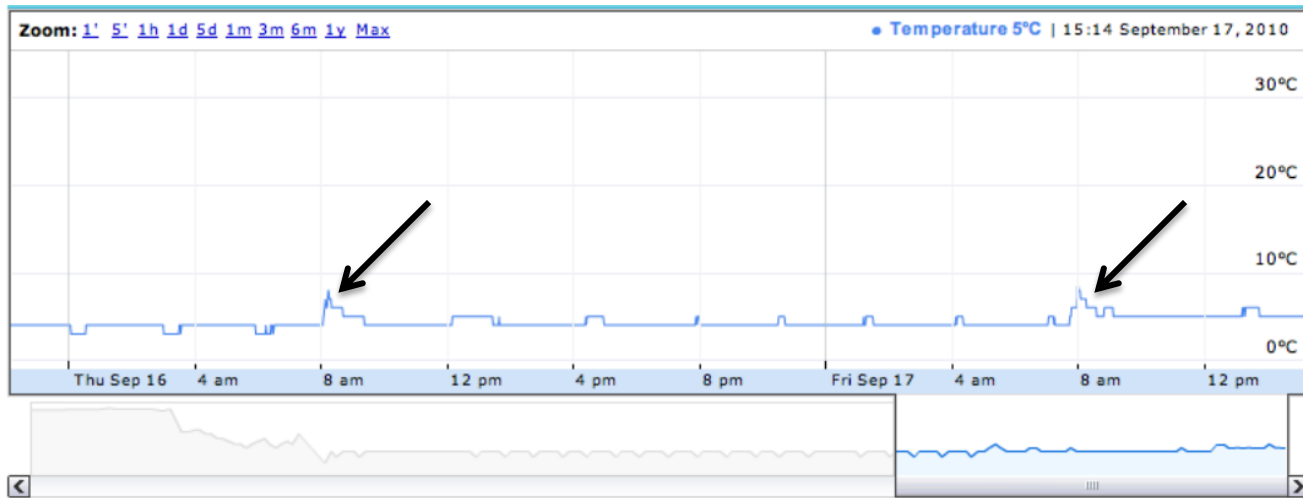
**Interior view showing sensor,
FridgeTag and vaccines**

- 6 FoneAstras deployed at 5 different facilities
 - National & Tirana district-level stores, Health Centers in Tirana
- Results to date
 - Freezing & high temperature alarms, power failures

Results

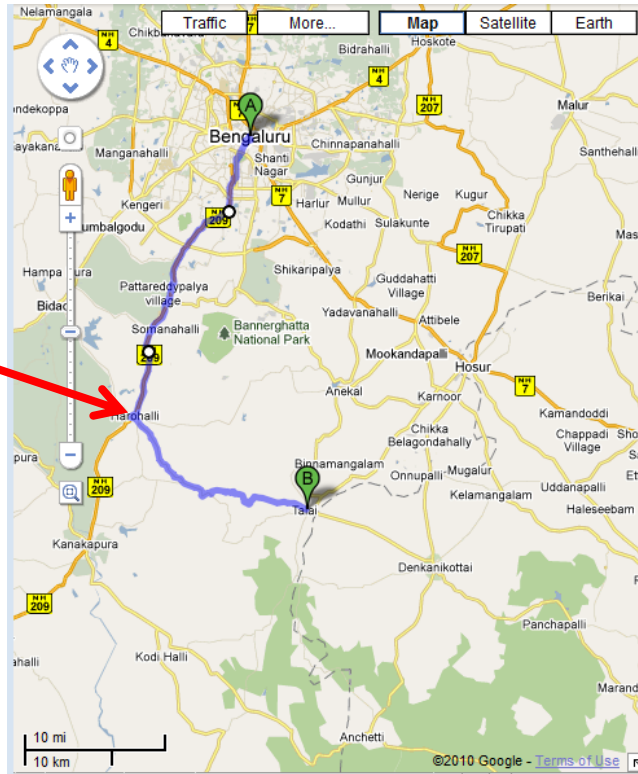


Power failures at a facility

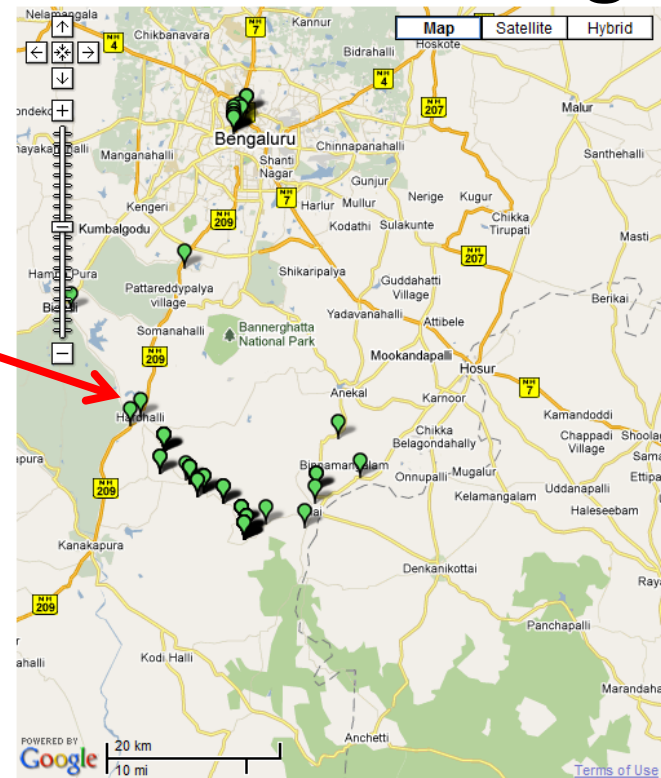


Detecting fridge door being opened

Cell Tower-ID based Location Tracking



Bangalore to Talai, a village in Tamil Nadu
(45 miles one-way)

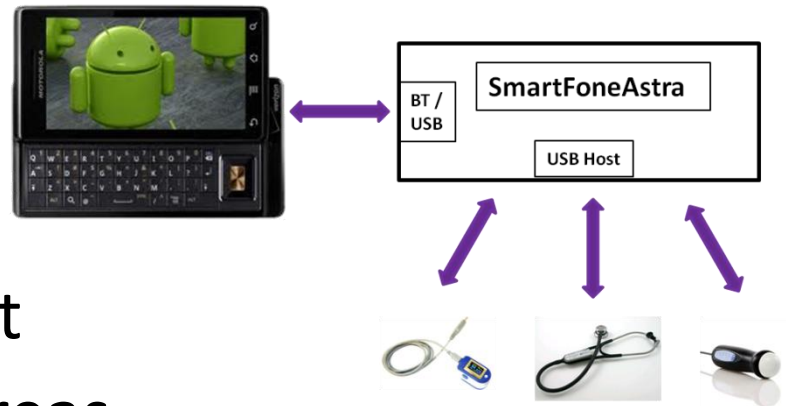


Green markers show location of cell towers "seen" during this trip

- FA connected to Nokia 1200 mobile phone
- Periodically scan for cell tower-ID
- "Unofficial" Google API to map cell tower-IDs to geo-coordinates
- Markers on map show location of cell towers "seen" by phone

Future Work

- What would it take to scale the system up?
 - What will we learn from it?
- VCC monitoring trials in Tunisia, Senegal
 - Location tracking in transit
 - Remote facilities, solar-powered equipment
- SmartFoneAstra
 - Integrate high-level sensors (e.g. ultrasound probe)
 - Healthcare delivery and point of care diagnostics in rural areas



Acknowledgements

- Microsoft Research India, Bangalore
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FoneAstra: Protect and Serve