

2013 hSITE Annual Research Review
Monday, 18 Nov., 2013
Montreal, Canada



UBIQUITOUS VITAL SIGN CAPTURE AND ASSET MANAGEMENT IN CLINICAL ENVIRONMENTS

Tho Le-Ngoc,

Quang-Dung Ho, Thanh-Ngon Tran, Robert Morawski

Yang Wu, Hoai-Phuoc Truong

Department of Electrical & Computer Engineering



Abstract



- This presentation reports system design, implementation and experimentation of a ubiquitous patient vital sign capture system (namely uVS) and a portable asset tracking and management system (namely pATMS) for clinical environments.
- uVS provides end-to-end connectivity between patient monitors and EHR by using smartphones. By replacing manual operations with automatic machine-to-machine (M2M) communications, uVS aims to enhance reliability, save time and costs for patient monitoring routines carried out in hospitals, clinics and emergency sites. uVS also allows medical staff to access patient files and charts from anywhere at any time in order to have fast and efficient responses to emergency situations.
- pATMS is a software suite built on top of an off-the-shelf real-time location system that allows users to locate any object of interest by simply using any networked devices (smartphones, tablets, ...). With pATMS, nurses and doctors can quickly search for medical devices (e.g., ultrasound machine, nursing stations, ...) that are required for patient care and treatment. This system also supports various smart asset management applications: track the usage and maintenance/software/firmware update history, prevent theft and vandalism, etc., of important and valuable hospital assets.

Content



Ubiquitous Vital Sign Capture



- System design and implementation a ubiquitous vital sign capture platform which provides end-to-end connectivity between patient monitors and EHR by using smartphones
- On-going research

Asset Management using RTLS



- Development of a software platform (on top of a RTLS) which brings maps and asset management application interfaces to personal mobile devices
- On-going research

These research items are for Task 3.1.3 (*Sensors and Ad-hoc Networking*) and Task 3.2.1 (*Multiple-antenna Wireless Communications*) of Theme 3 (*Enabling Networks and Technologies*)

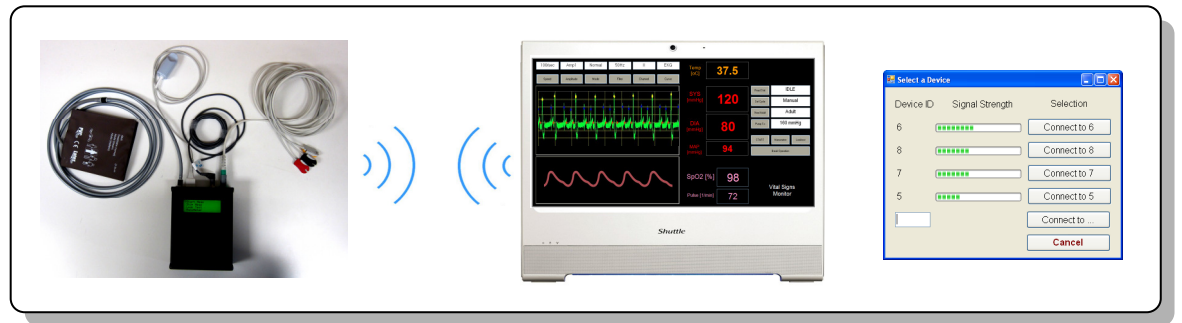
Ubiquitous Vital Sign Capture



Ubiquitous Vital Sign Capture



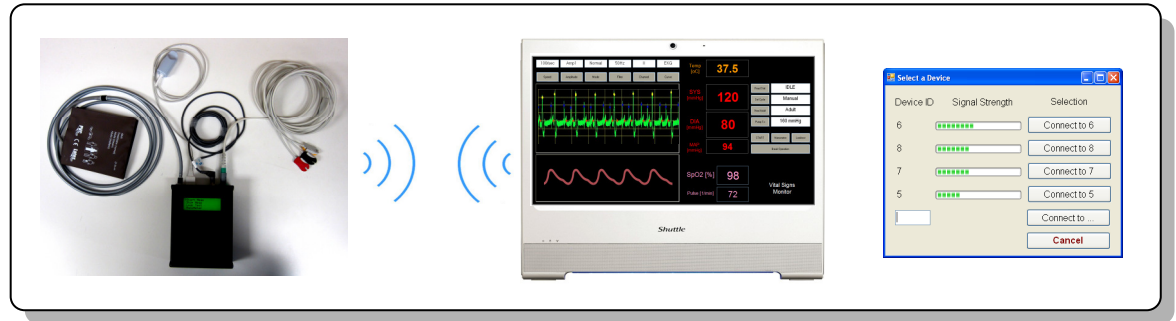
Wireless Continuous Patient Monitoring in Emergency Room



Ubiquitous Vital Sign Capture

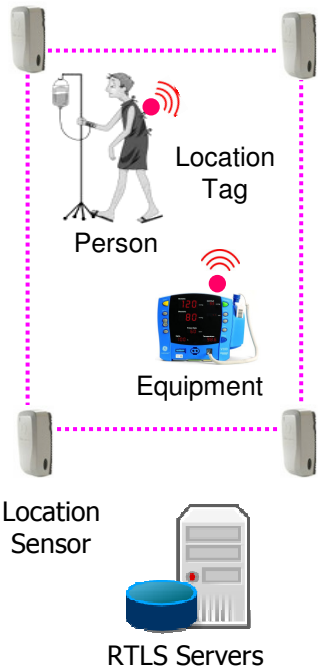


Wireless Continuous Patient Monitoring in Emergency Room



Real-time Location System (RTLS)

WiFi
UWB



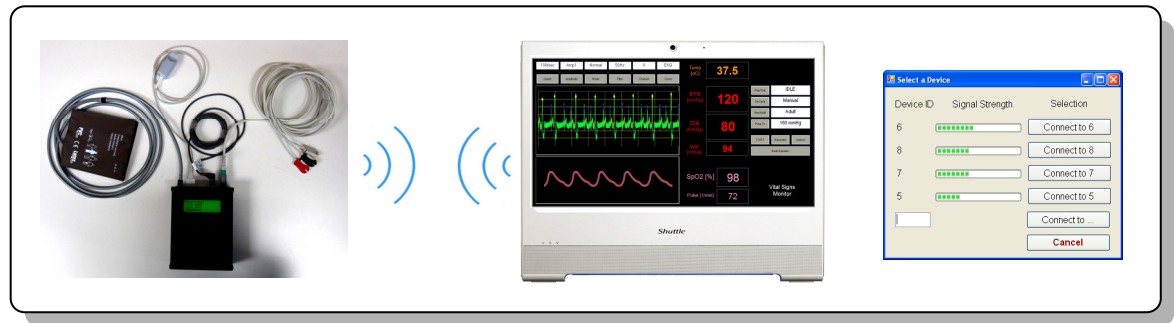
Portable RTLS and Asset Management Applications



Ubiquitous Vital Sign Capture



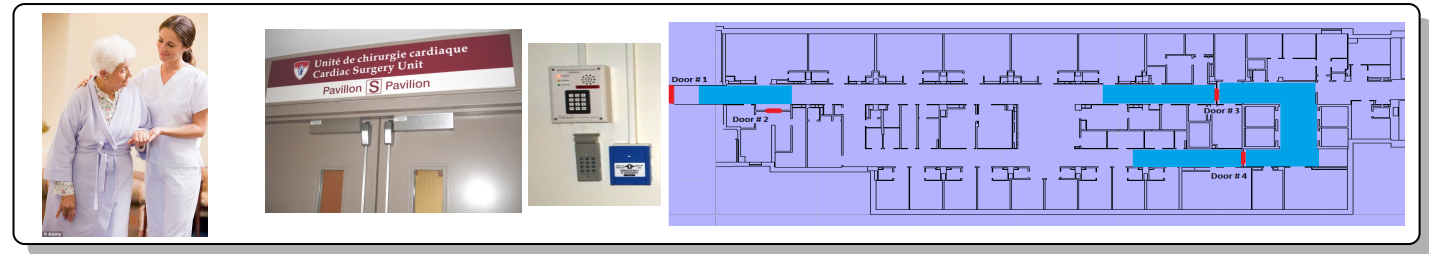
Wireless Continuous Patient Monitoring in Emergency Room



Portable RTLS and Asset Management Applications



Elderly Patient Mobility Monitoring and Restraining System



Real-time Location System (RTLS)

WiFi
UWB



Equipment

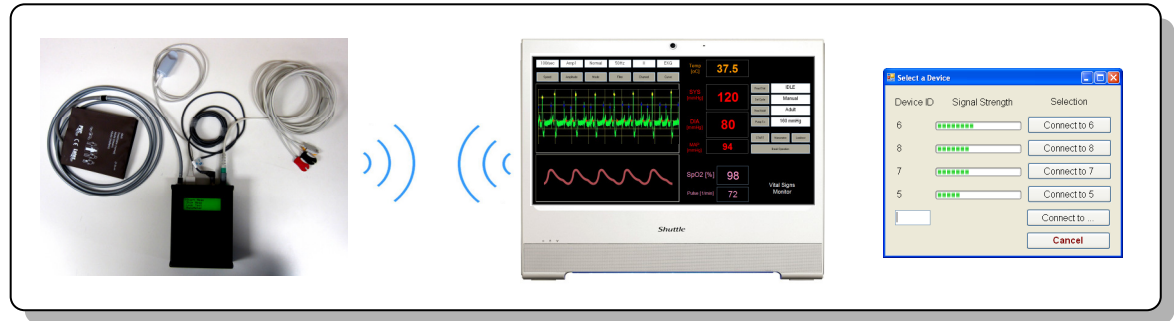
Location Sensor

RTLS Servers

Ubiquitous Vital Sign Capture



Wireless Continuous Patient Monitoring in Emergency Room



Real-time Location System (RTLS)

WiFi
UWB



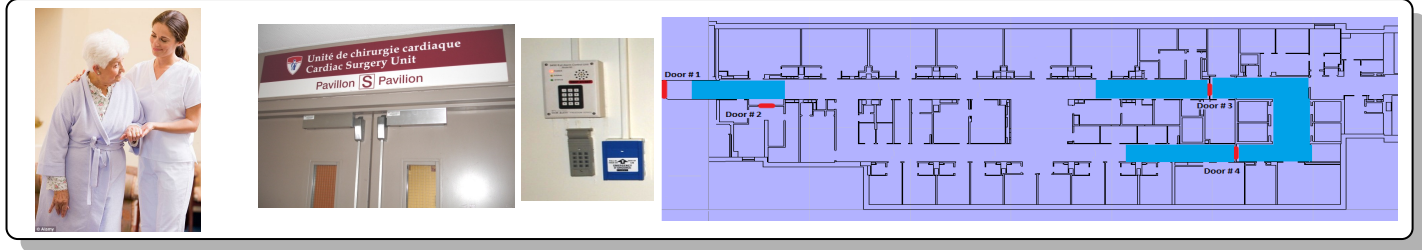
Location Sensor

RTLS Servers

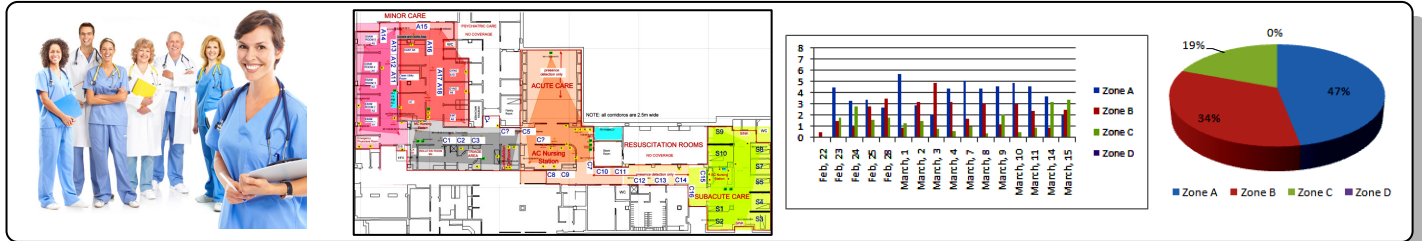
Portable RTLS and Asset Management Applications



Elderly Patient Mobility Monitoring and Restraining System



Clinical Workflow Analysis and Improvement





UBIQUITOUS AND END-TO-END VITAL SIGN CAPTURE USING SMARTPHONES



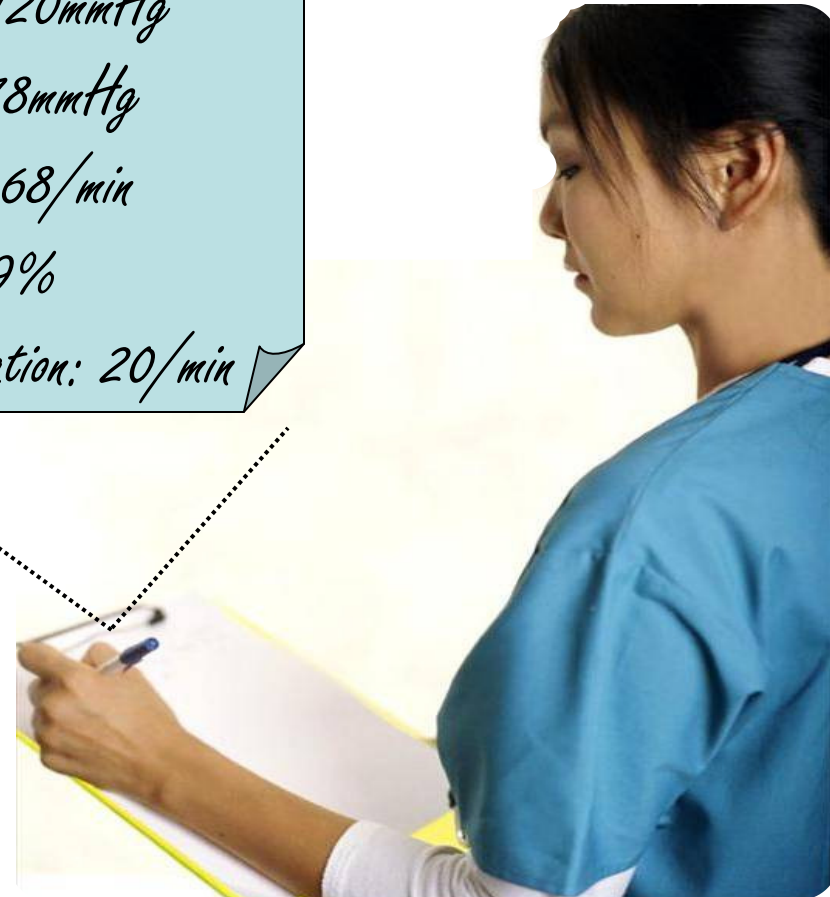


Manual Vital Sign Capture



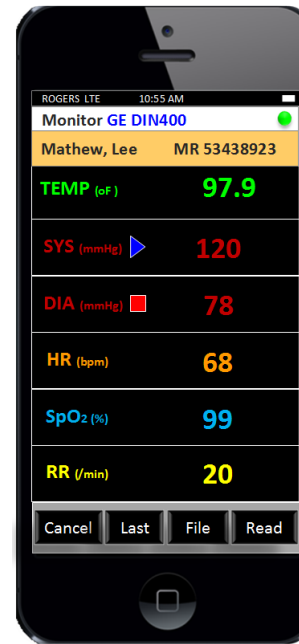
Temperature: 97.9oF
SYS: 120mmHg
DIA: 78mmHg
Pulse: 68/min
Sat: 99%
Respiration: 20/min

Read and then record data by **hand writing**





Automatic Vital Sign Capture



Record data by
one click





Summary

- Develops a ubiquitous vital sign capture platform, namely uVS, which provides **end-to-end** connectivity between patient monitors and EHR by using smartphones
- By replacing **manual** operations with **automatic M2M** communications, uVS aims to enhance **reliability**, save **time** and **costs** for patient's monitoring routines carried out in hospitals, clinics and emergency sites
- uVS also allows medical staff to access to patient health conditions and other information (e.g., medications, prescriptions, medical treatment history, etc.) from EHR **from anywhere at anytime** in order to have fast and efficient responses to emergency situations



Advantages

Reduce mistakes

manual data input is replaced by M2M fully automatic data capture

Save time

all vital signs are captured by one click

Simplicity

a universal GUI can be used with different patient monitor devices

Cost efficiency

existing patient monitors are used

Ubiquitous

data is accessible everywhere

Environment

paperless workflow saves the environment



Applications

Hospitals

Nurses periodically measure patient's VSs



Emergency situations

Attendants report victim's conditions to hospitals to get additional supports



Home healthcare

Nurses/patients regularly check patient's health conditions



Remote diagnosis

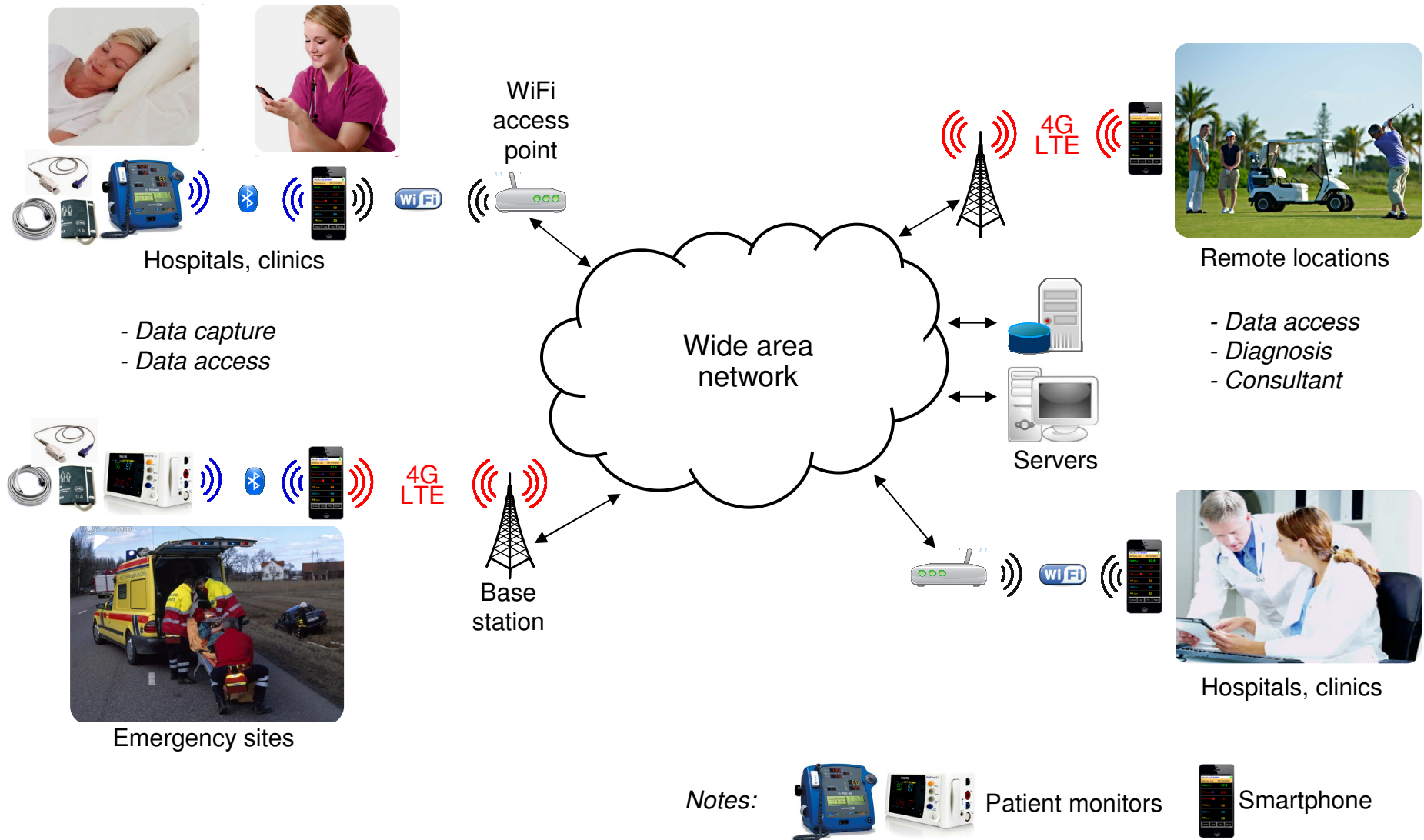
Specialists help doctors diagnose patients requiring special attention



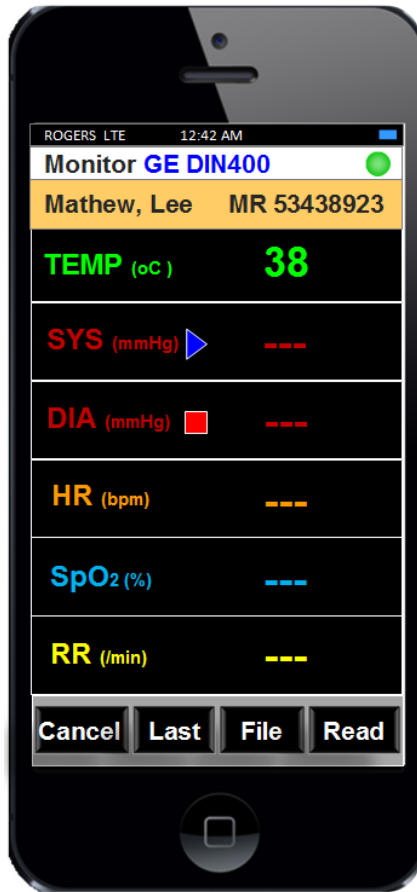


System Architecture

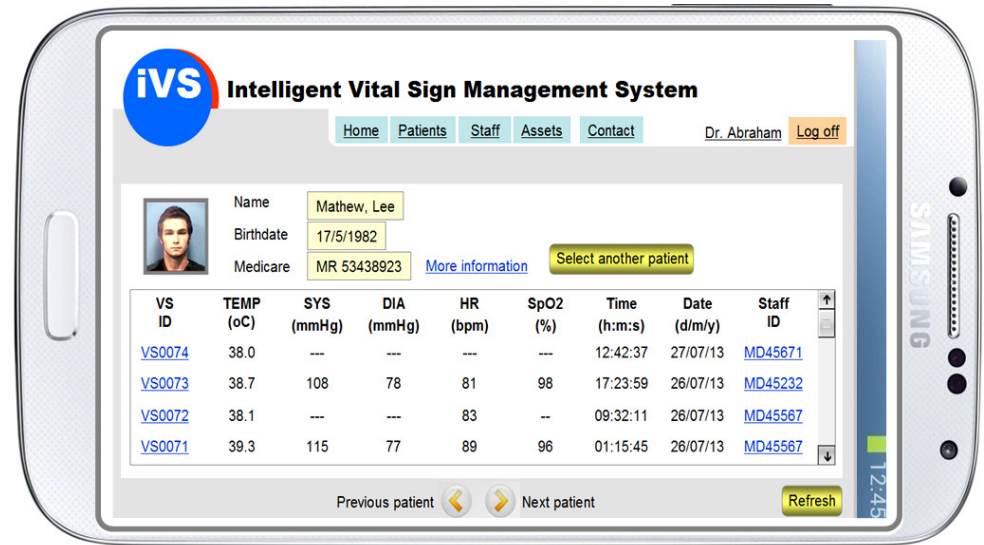
End-to-end connectivity



End-to-End Connectivity



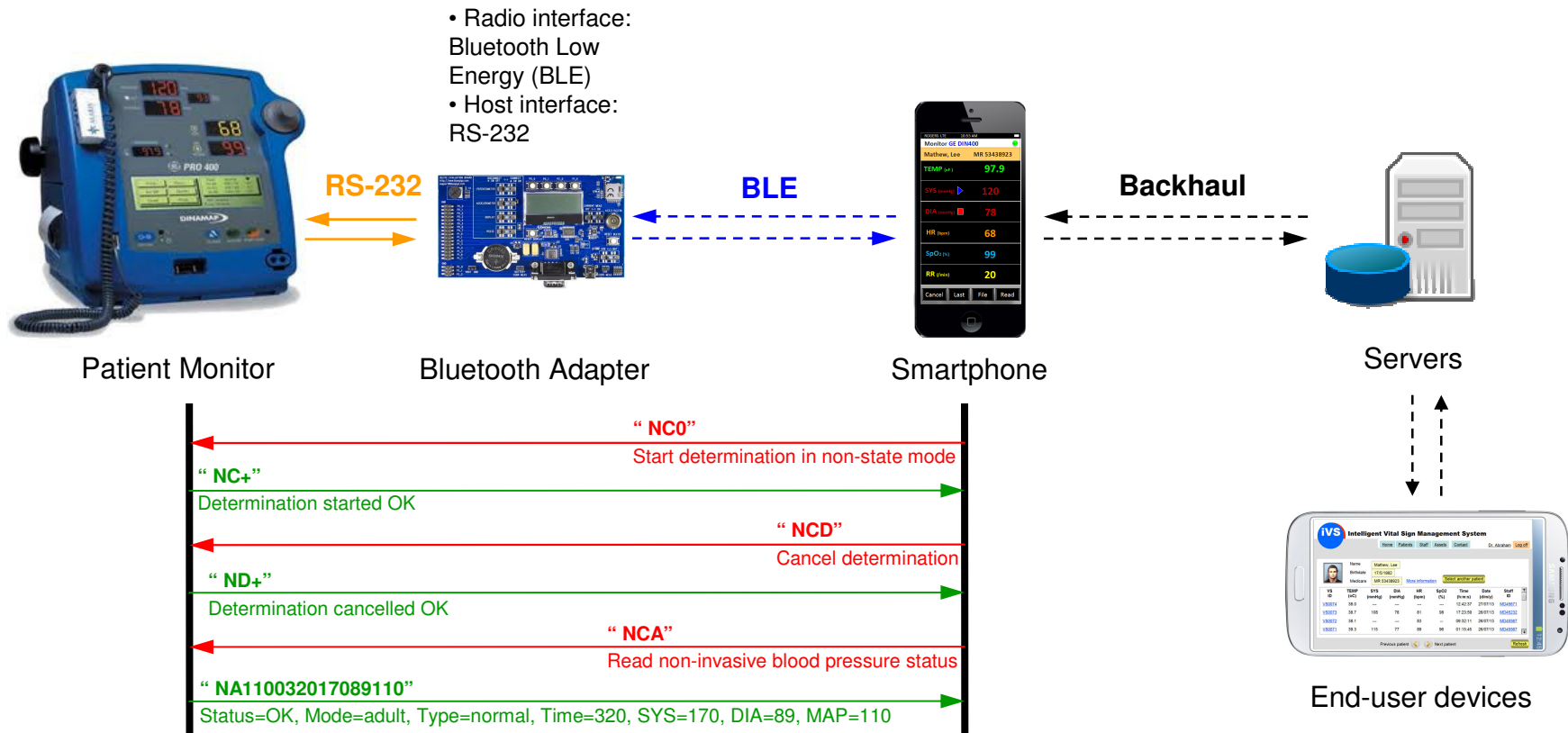
VS capture
(patient bedside)



Patient file access
(any location with Internet connection)



M2M Communications



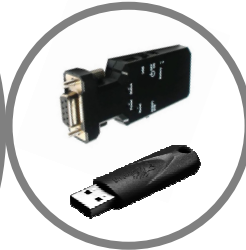
System Design



Patient Monitors



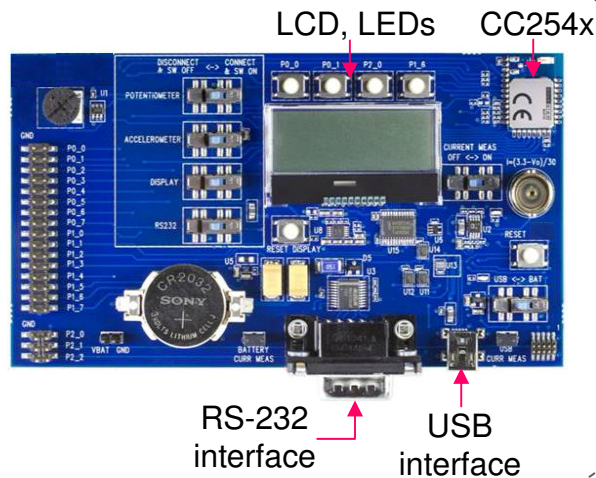
BLE Adapters



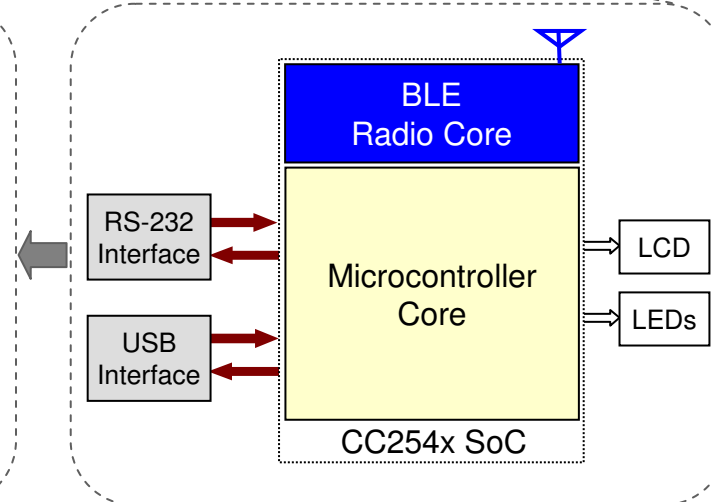
Personal Smart Mobile Devices



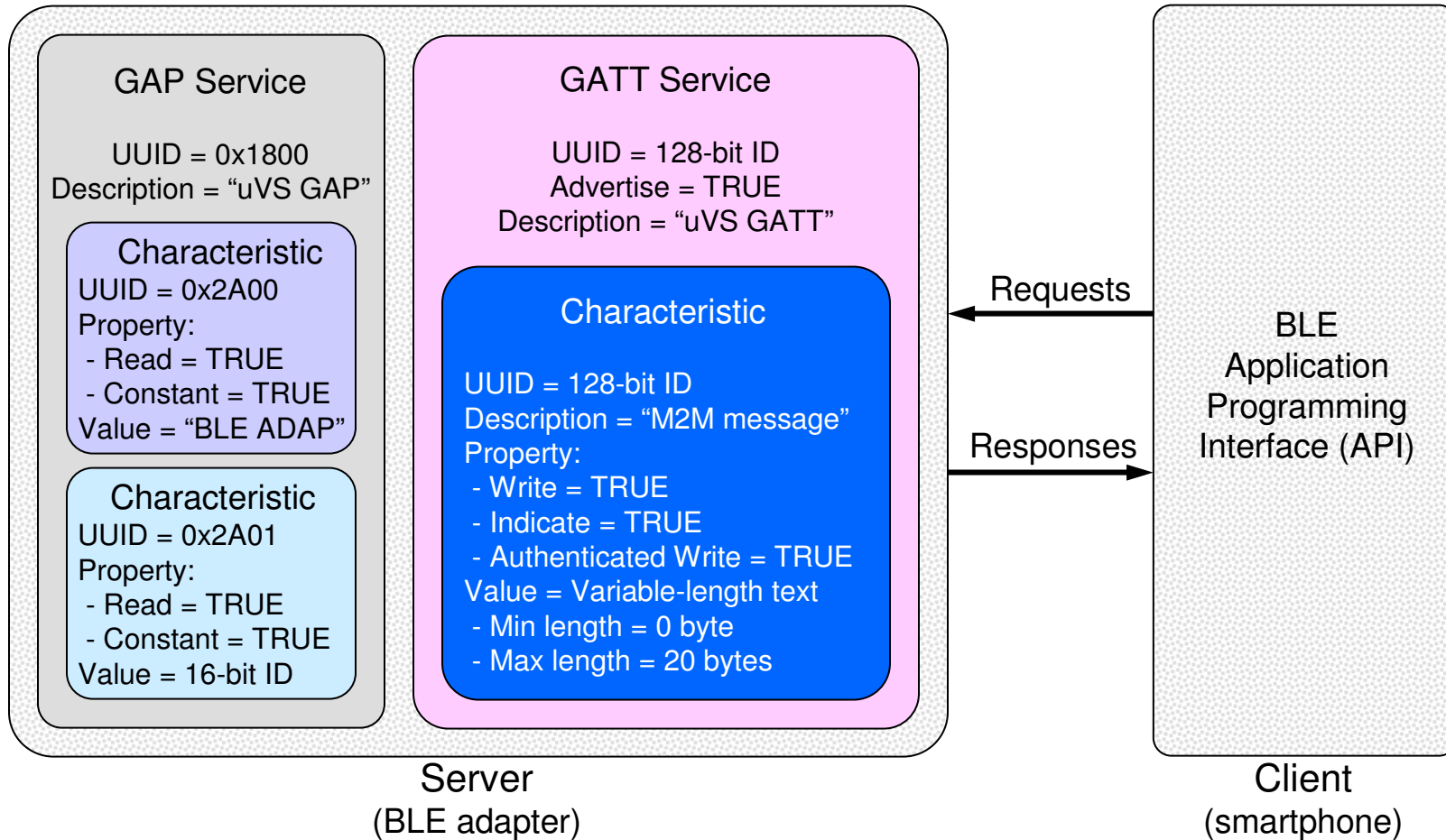
Development Board



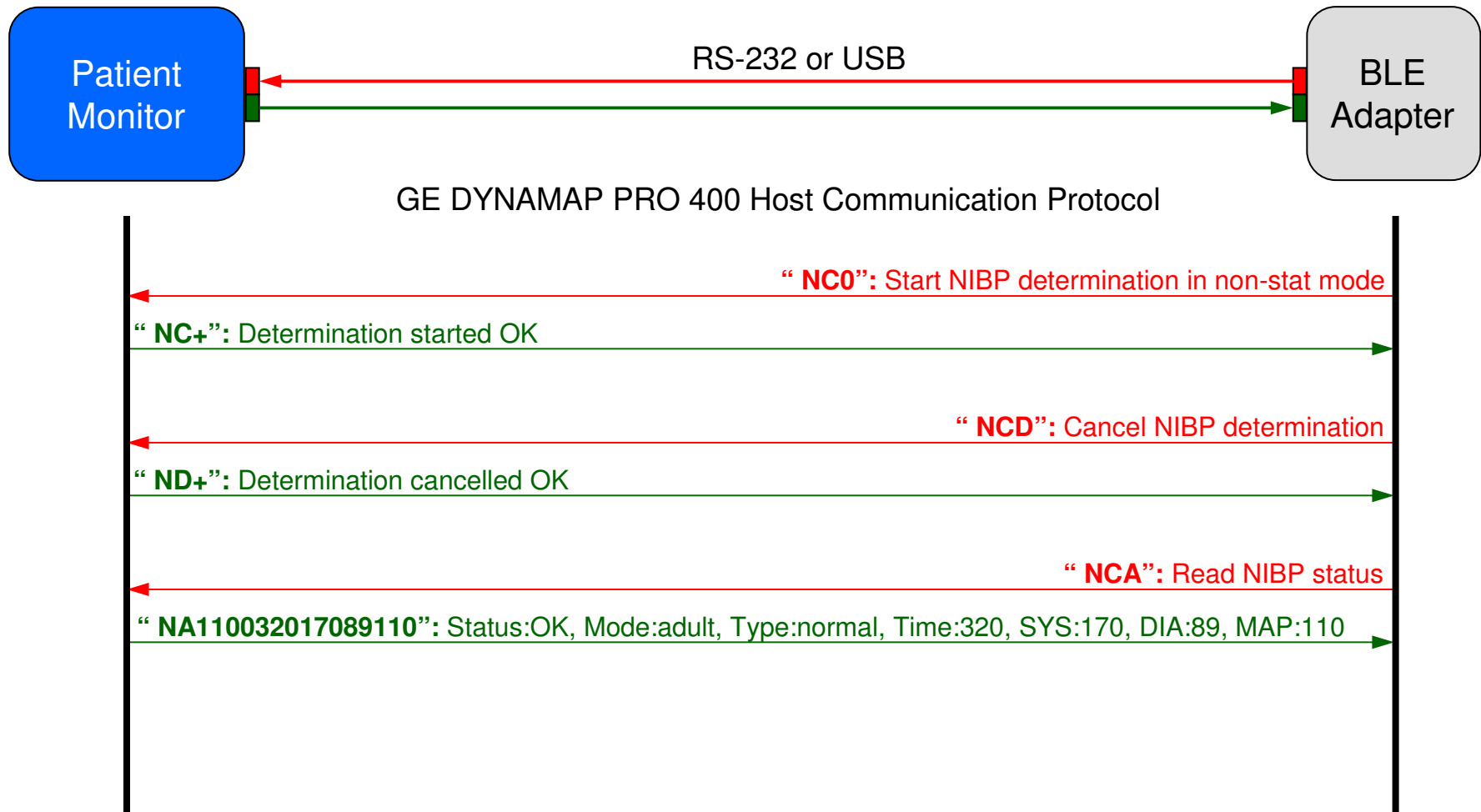
System Design



BLE Profiles



Host Comm. Protocol





Patient monitor

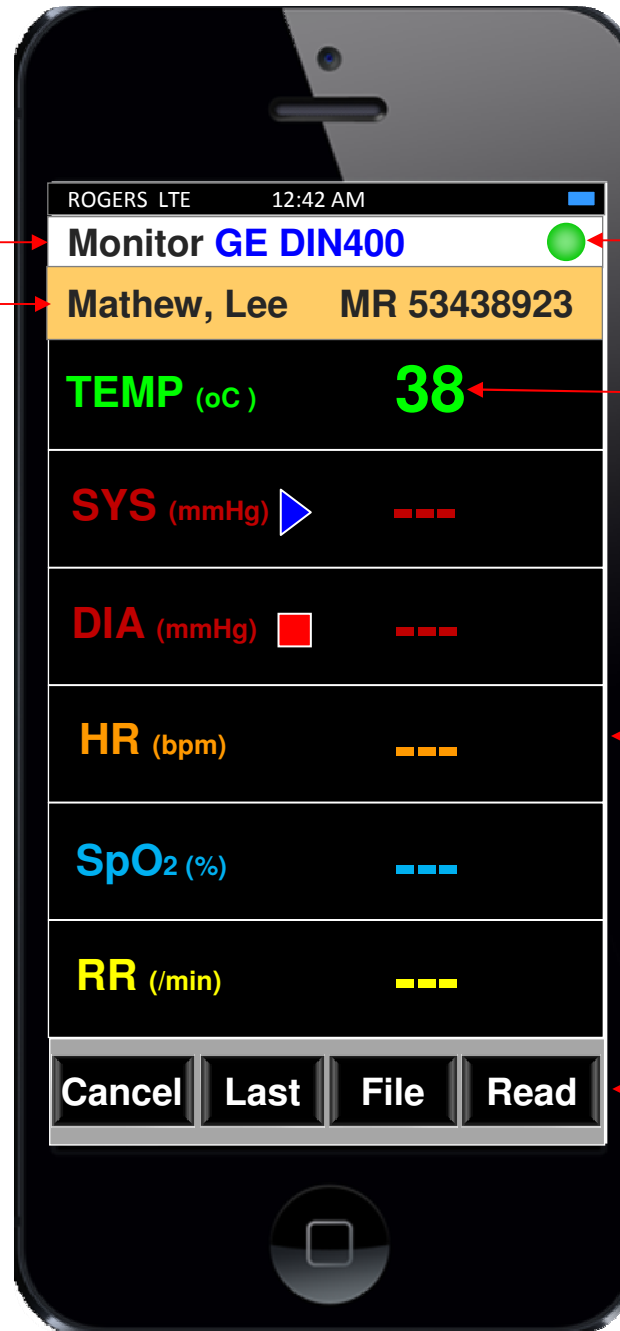
Indicates brand and model of the monitor currently paired with the smartphone

Patient

Indicates name and ID of the patient currently monitored by the monitor
Tab it to select to another patient

- ▶ Start NIBP determination
- Stop NIBP determination

GUI to capture VSs



Connection status light

- **Red**: BLE interface is disabled
- **Orange**: BLE interface is enabled but no pair is established
- **Green**: BLE pair was established and data communications is ready

Value field:

- **3 dashes (---)**: data is not read from the patient monitor
- **A given value**: data is ready to [File] to EHR
Tab it to query data from the patient monitor

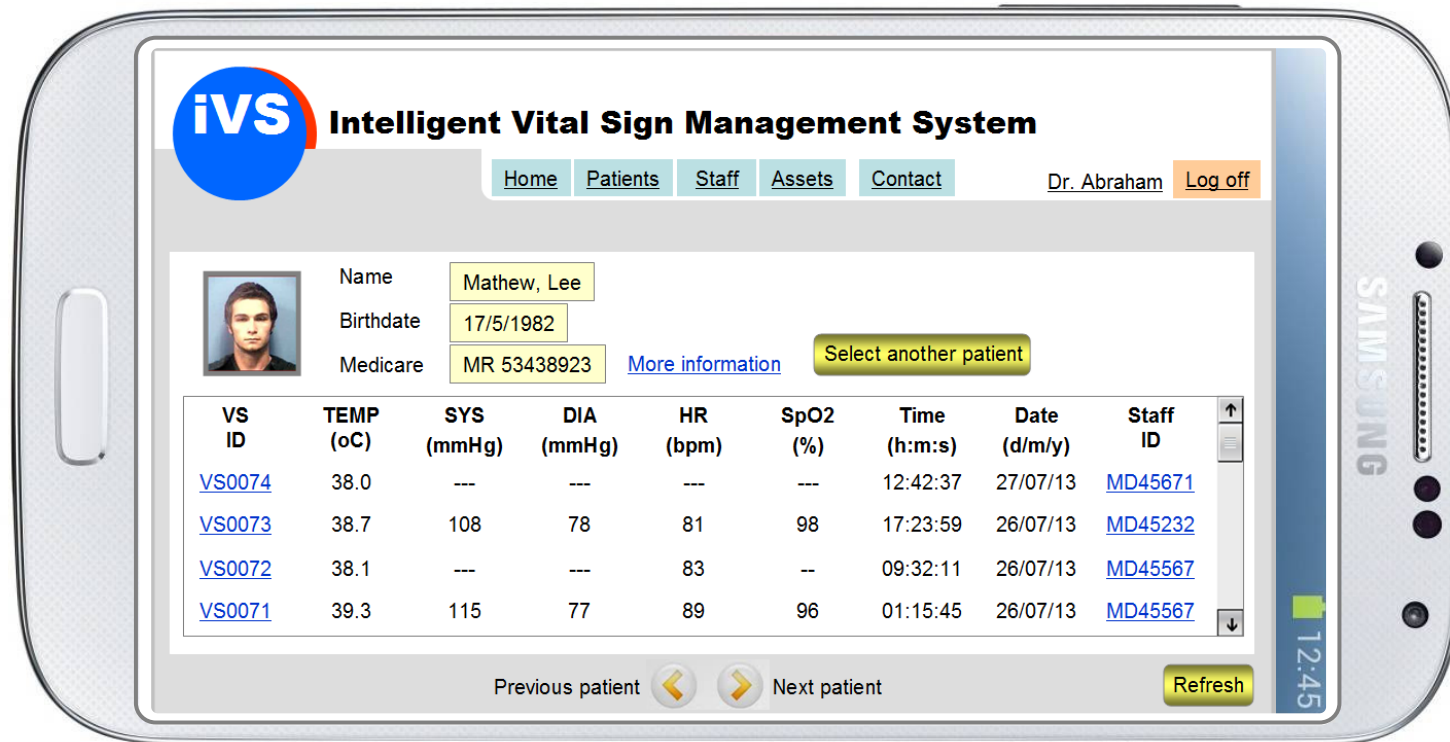
VS from patient monitor

- **Black background**: this VS is supported by the monitor
- **Gray background**: this VS is not supported by the monitor

Action buttons

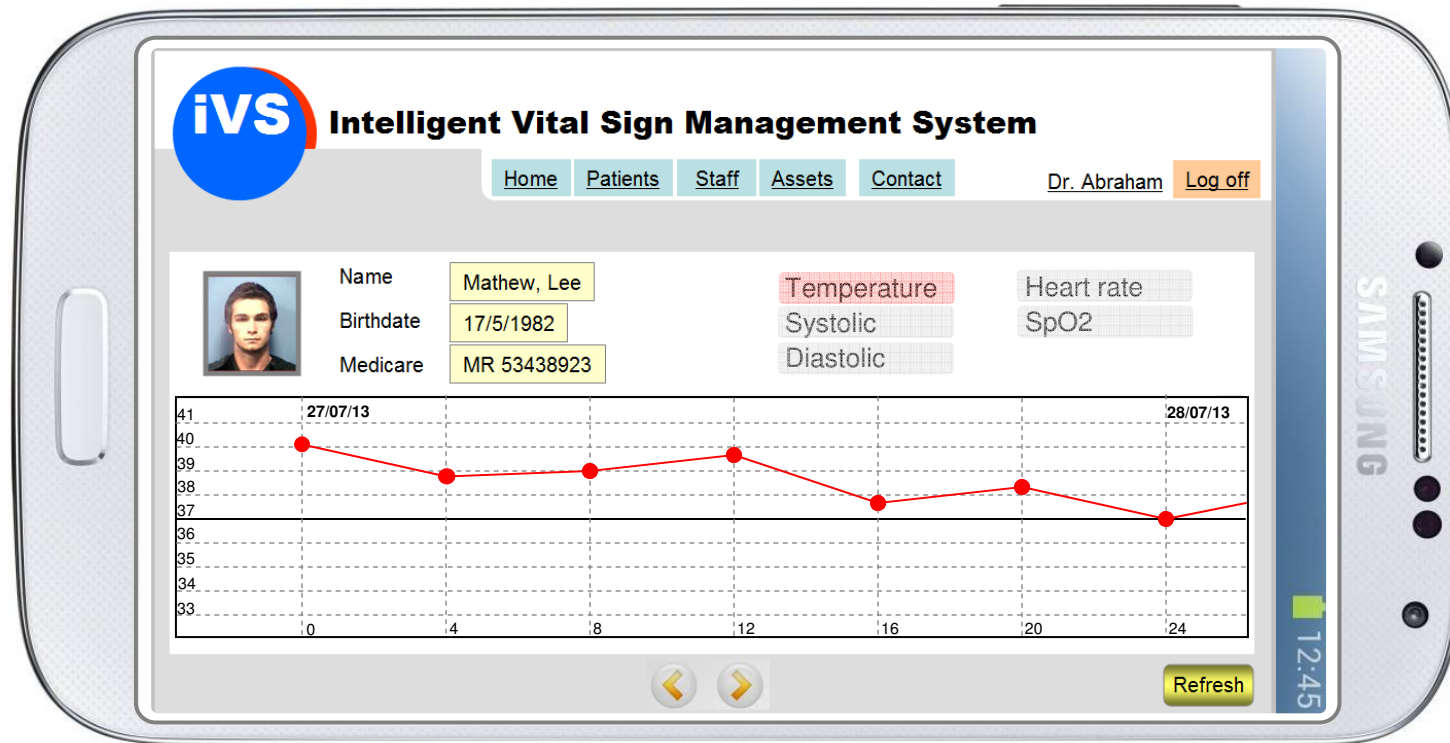
- **Read**: triggers a new set of readings
- **File**: saves the all readings to EHR
- **Last**: displays the last reading
- **Cancel**: aborts the VS capture

End-user Interfaces



Patient file

End-user Interfaces



Patient charts



On-going Research

- **Wireless communications and networking:** key technologies enabling ubiquitous patient monitoring
 - Routing and dynamic configuration in wireless medical sensor networks: interference management, energy efficiency, reliability and robustness, quality of service provisioning, ...
 - Electromagnetic-interference-aware routing
 - Cluster-based routing
 - Multipath routing, network-coding-aware routing
 - Cloud computing & wireless virtualization
- **User interface design and workflow optimization:** user-oriented, easy to use, convenient & efficient, time & cost saving, ...



PORTABLE RTLS AND ASSET MANAGEMENT APPLICATIONS

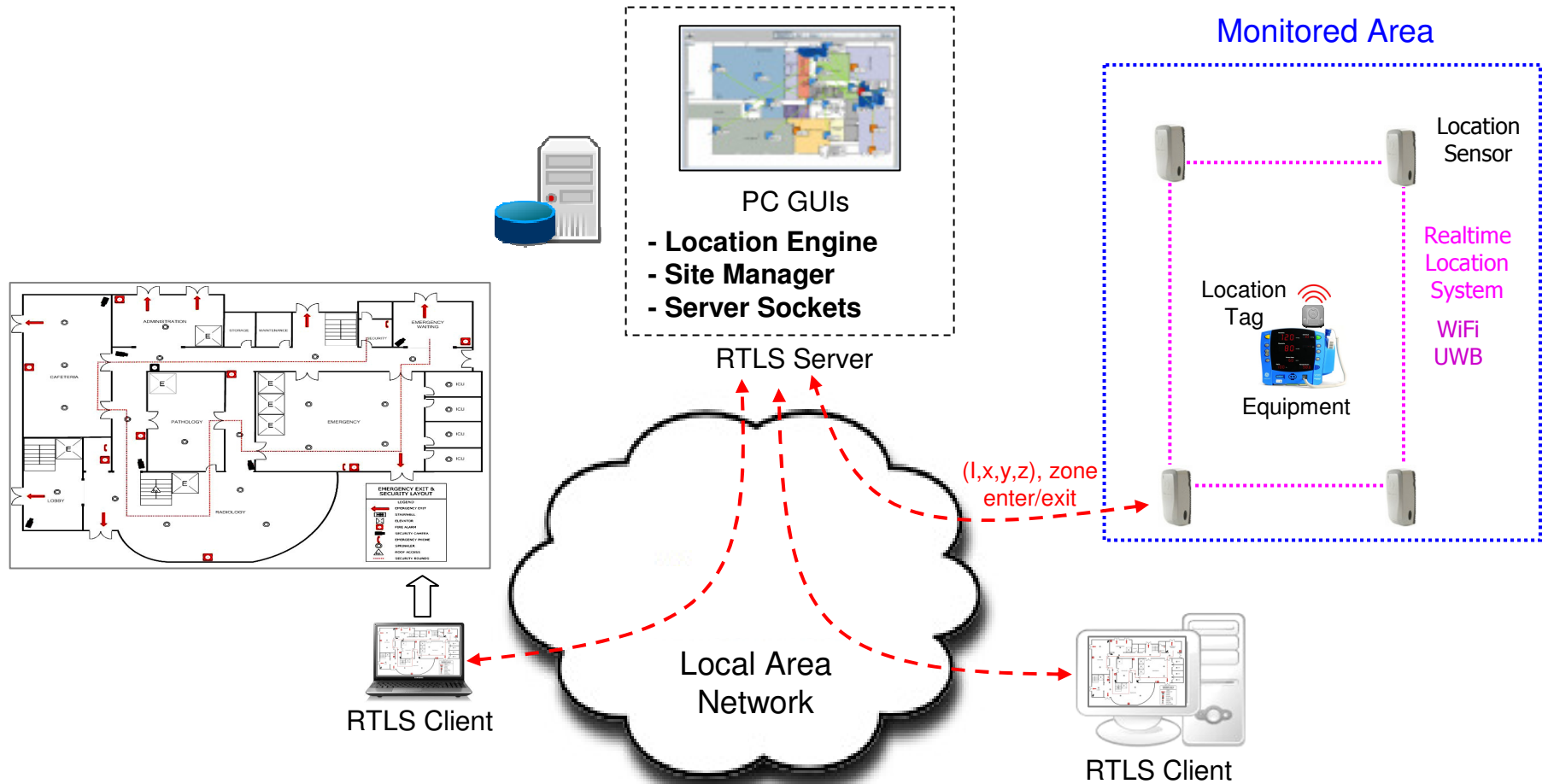


Real-time Location System (RTLS)



- **RTLS** provides information regarding where people and assets are located
- **Various applications in healthcare**
 - Locate healthcare personnel
 - Track the movements of patients
 - Track equipment
 - Assist emergency response
 - Analyze and improve clinical workflows
- **Benefits**
 - Improve patient safety
 - Improve patient/family satisfaction
 - Boost productivity of nurses and caregivers

Existing RTLSs



- Access to the map is within the LAN
- Time-consuming setup procedure is required on each RTLS client
- Applications are very limited



Summary

- Builds up a software platform on top of a RTLS to allows users to locate any object of interest by simply using smartphones from **anywhere** and at **any time**
- With this platform, nurses and doctors can quickly search for medical devices (e.g., ultrasound machine, nursing stations, ...) that are required for patient care and treatment
- This platform also supports various smart asset management applications: track the usage and maintenance/software/firmware update history, prevent thieves and vandalisms, etc., of important and valuable hospital assets



Advantages

Convenience

applications are available at hands

Save time

assets in need can be searched quickly

Simplicity

no configuration is required at end-user devices

Efficient mgt.

Loss/vandalism of valuable devices are prevented

Cost efficiency

no specialized terminal is required, only smartphones

Ubiquitous

services are accessible everywhere



Applications

Tracking

Track the real-time locations of assets

Find

Find current locations and status of a given asset in need

Reserve & Return

Register to use and return a given asset

Alert & Protect

Notify whenever an asset is moving out of its designated area

History & Maintenance

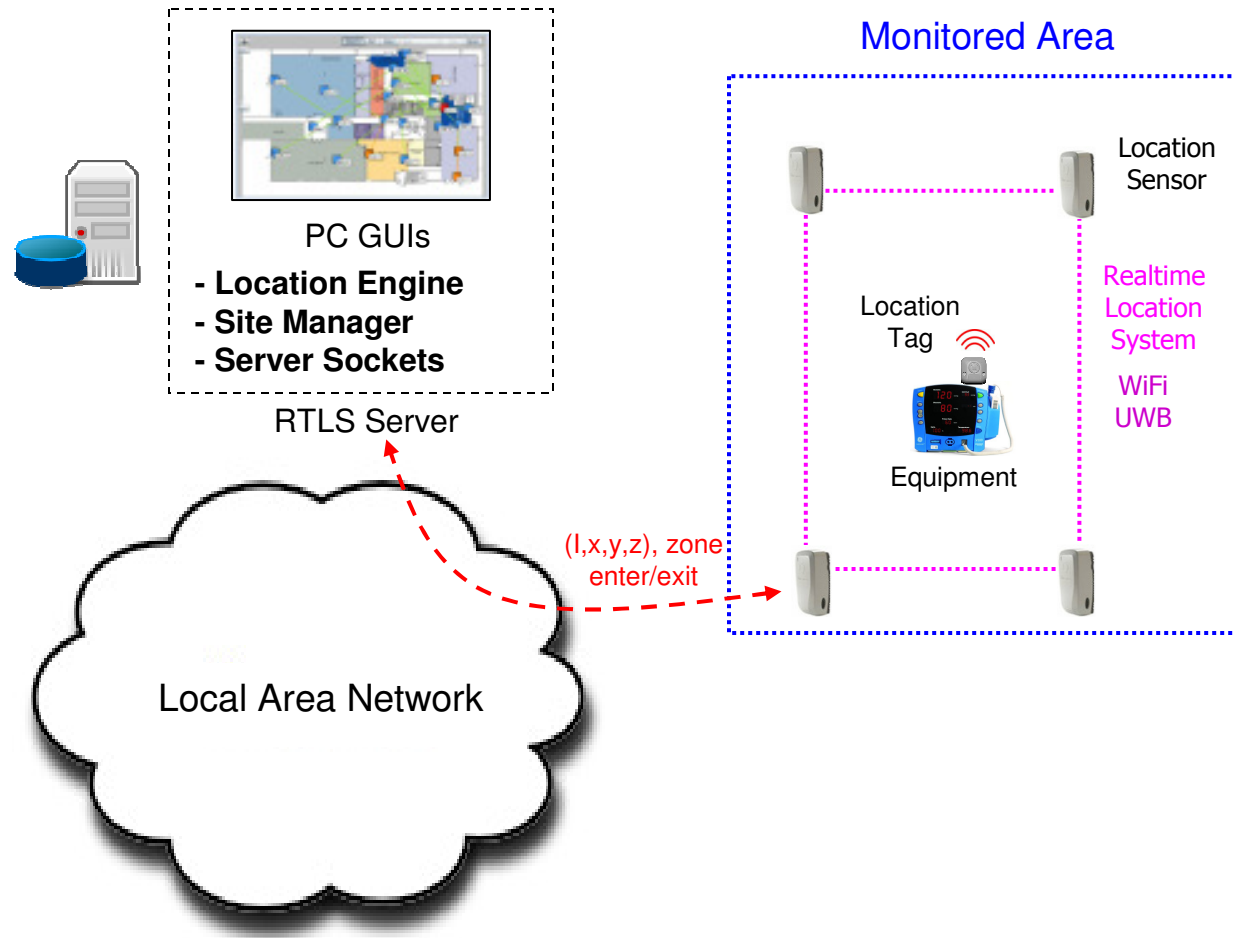
Usage statistics and automatic hardware/software maintenance reminding

Inventory Management

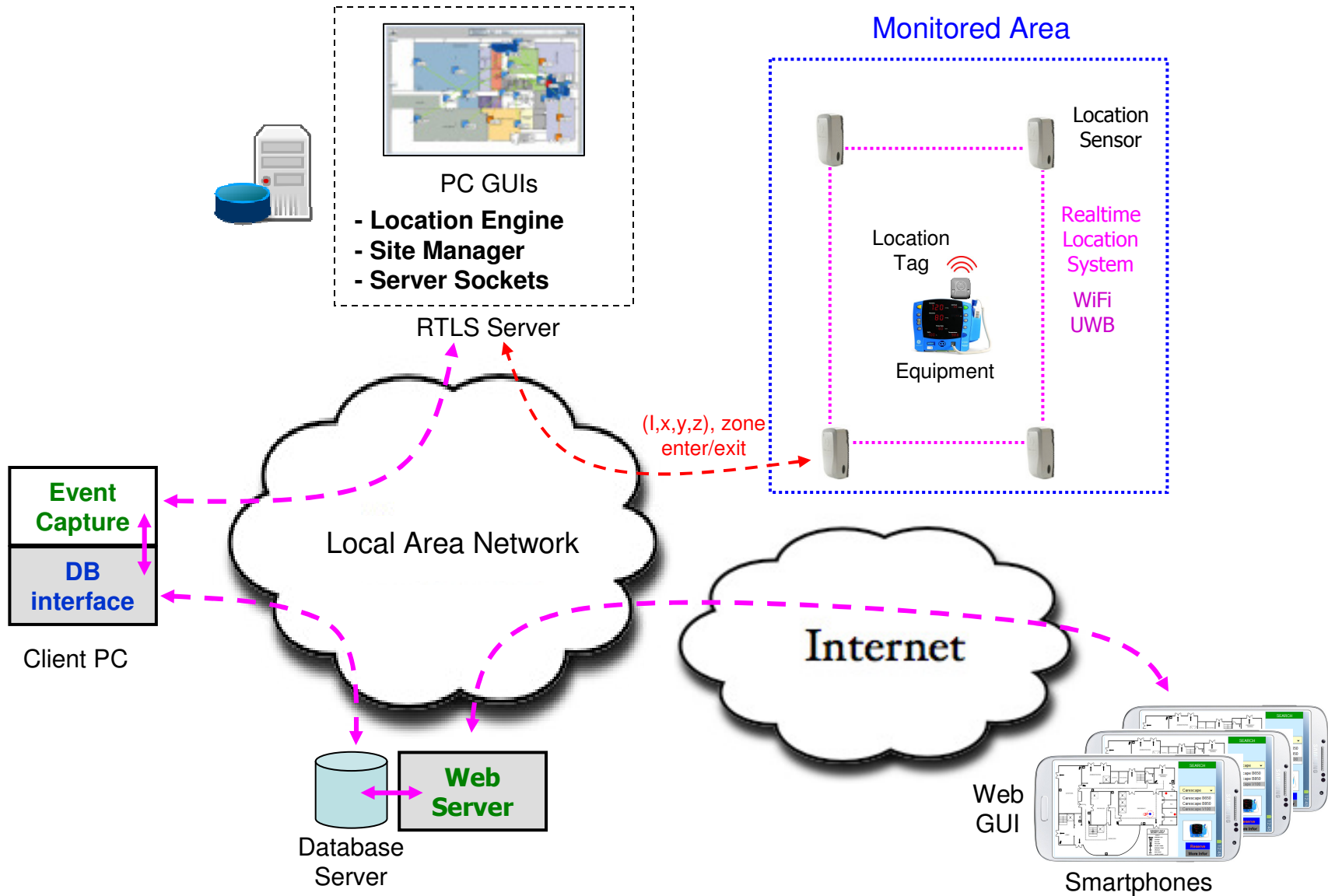
Trace the availability of assets



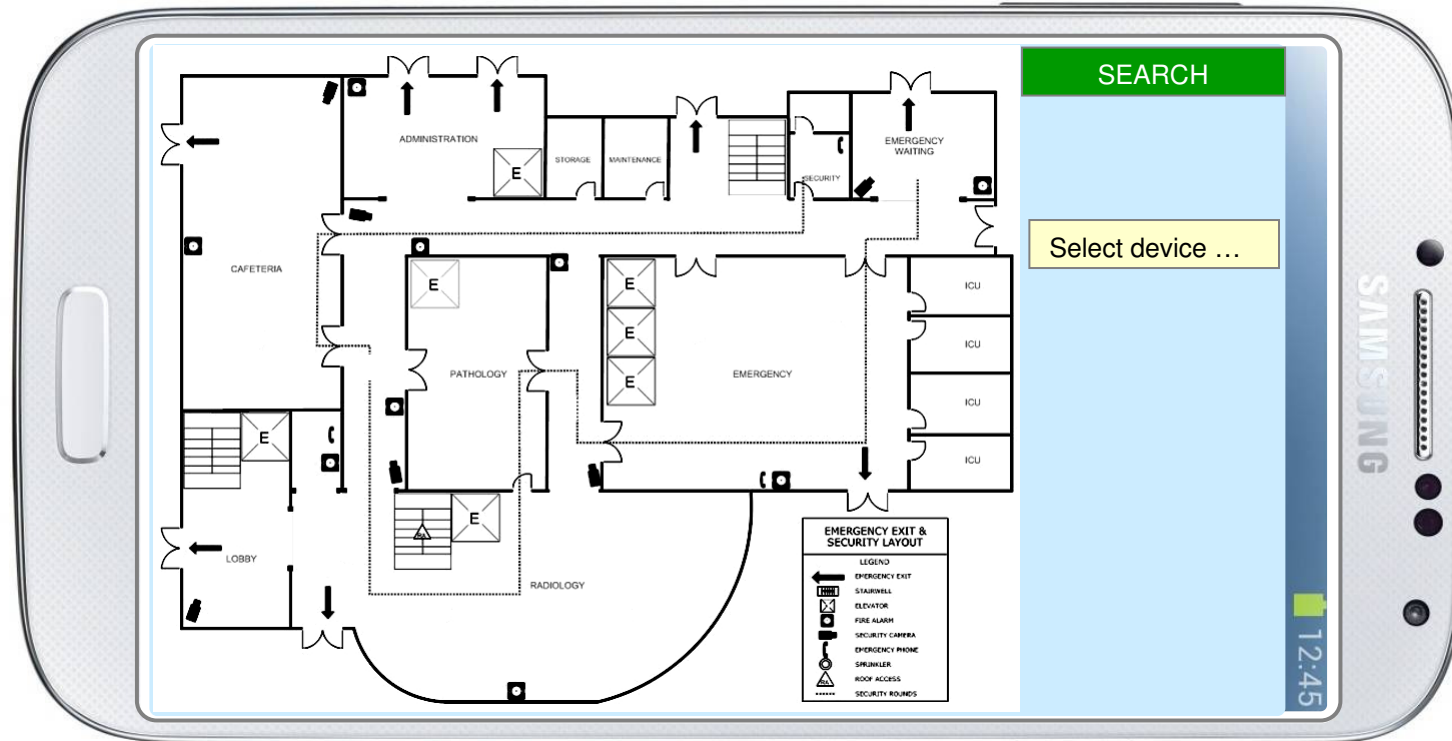
Overall System Architecture



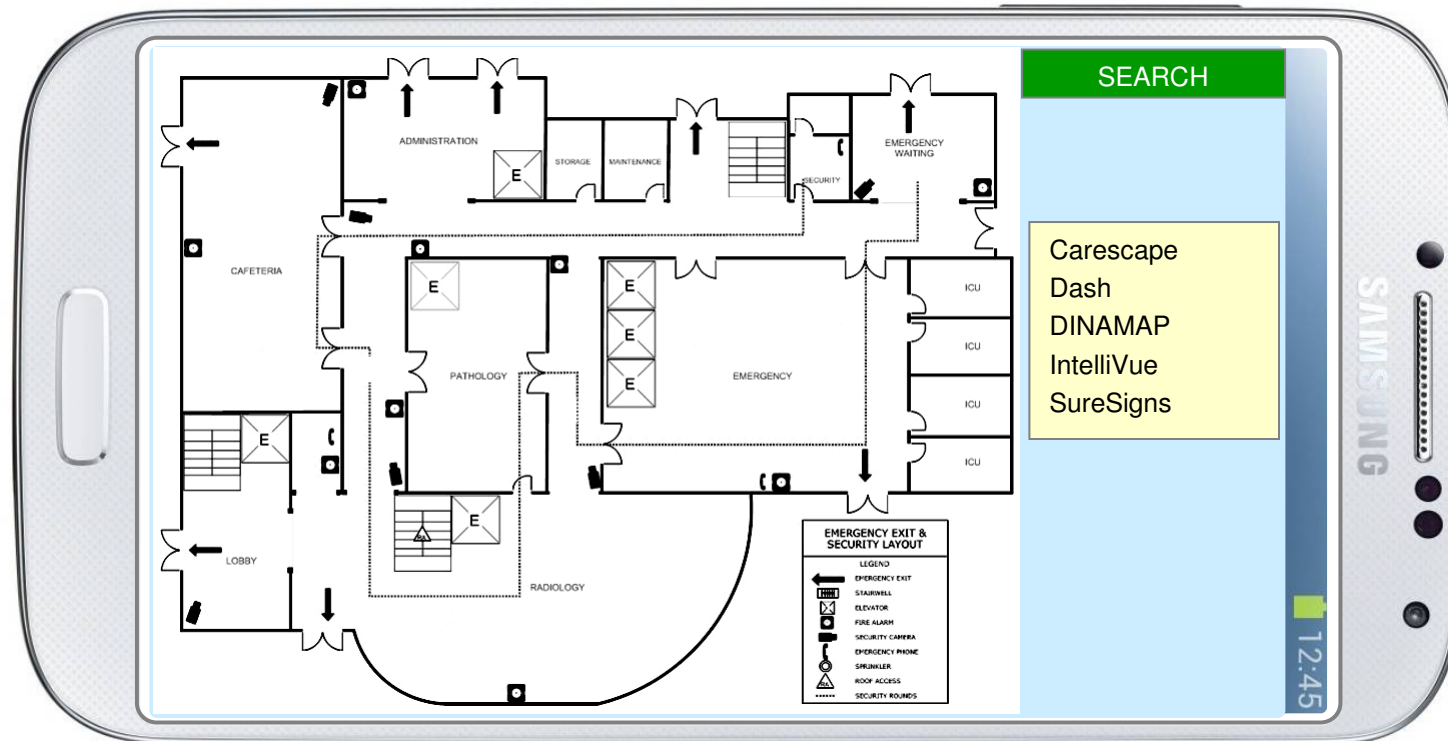
Overall System Architecture



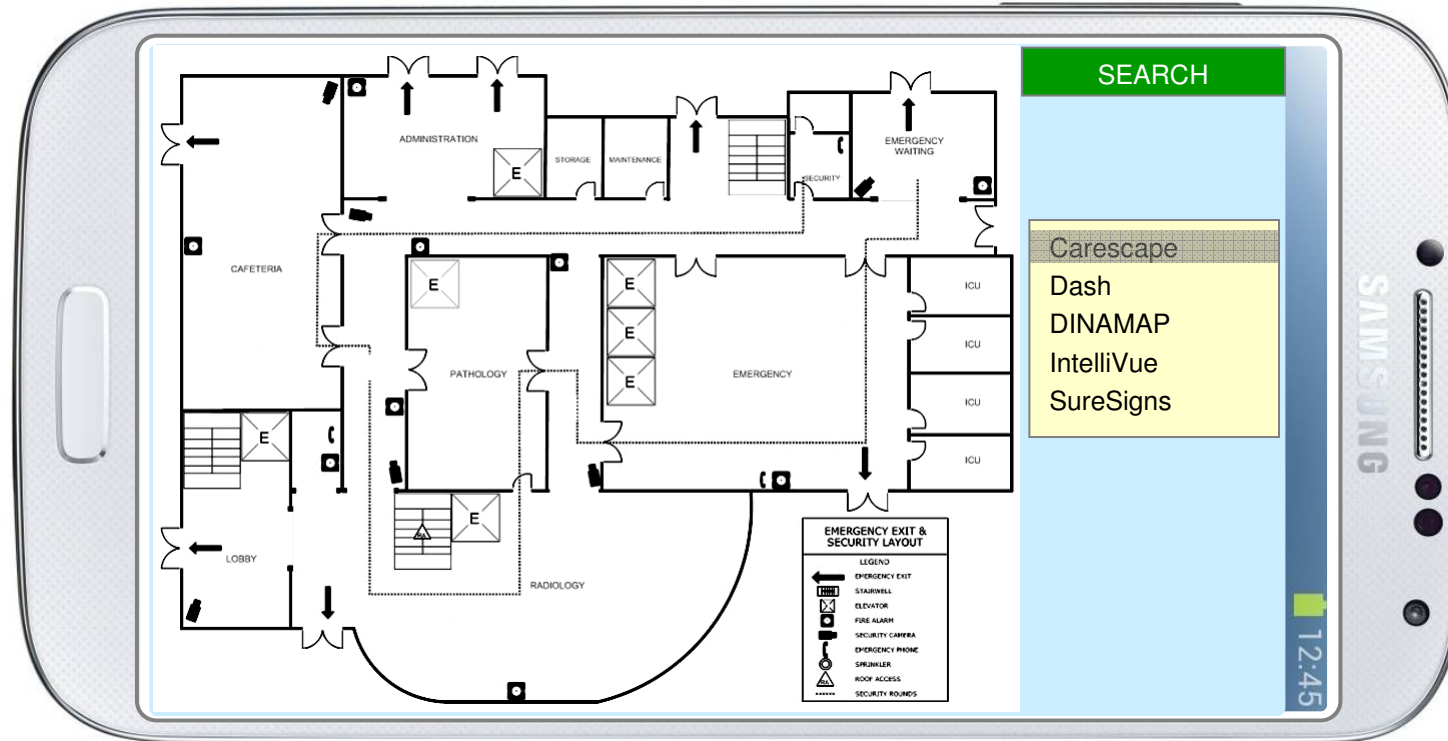
Application Prototype



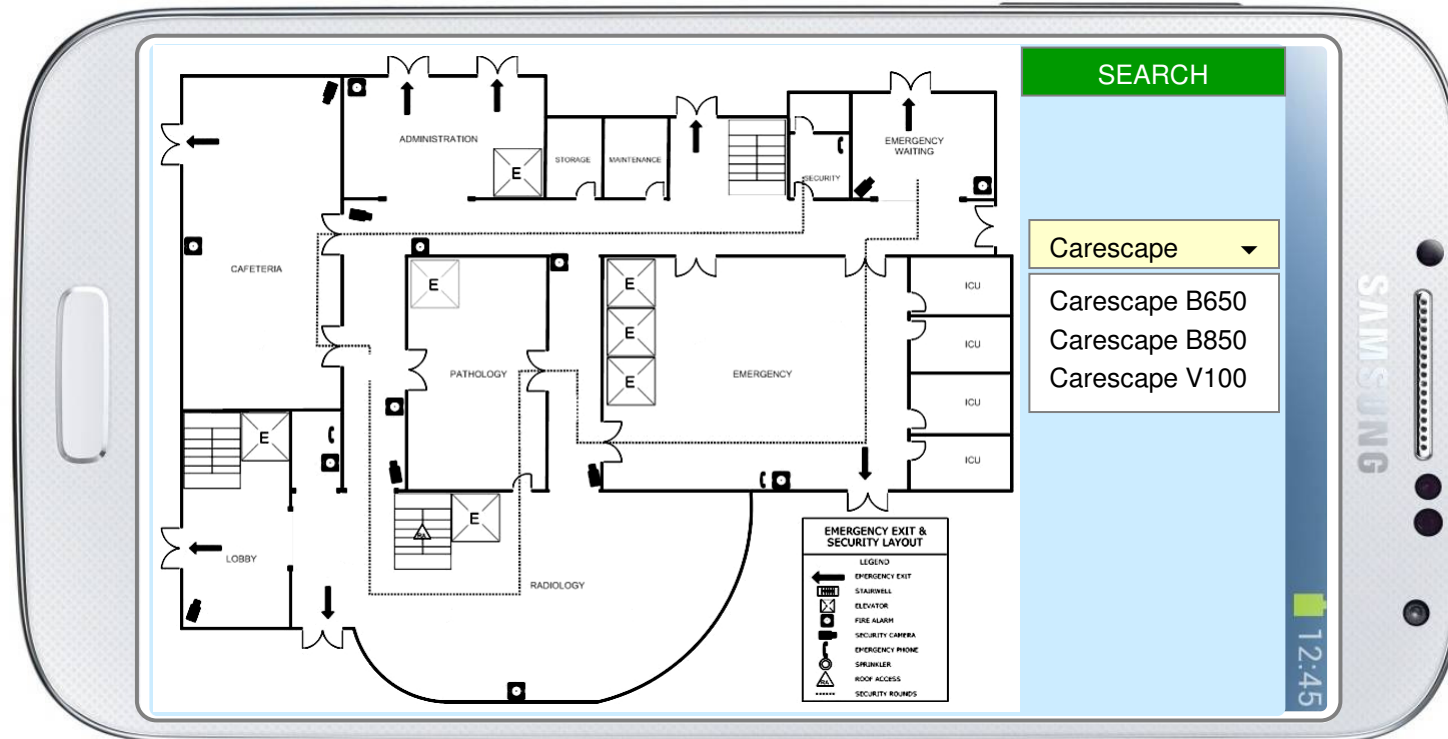
Application Prototype



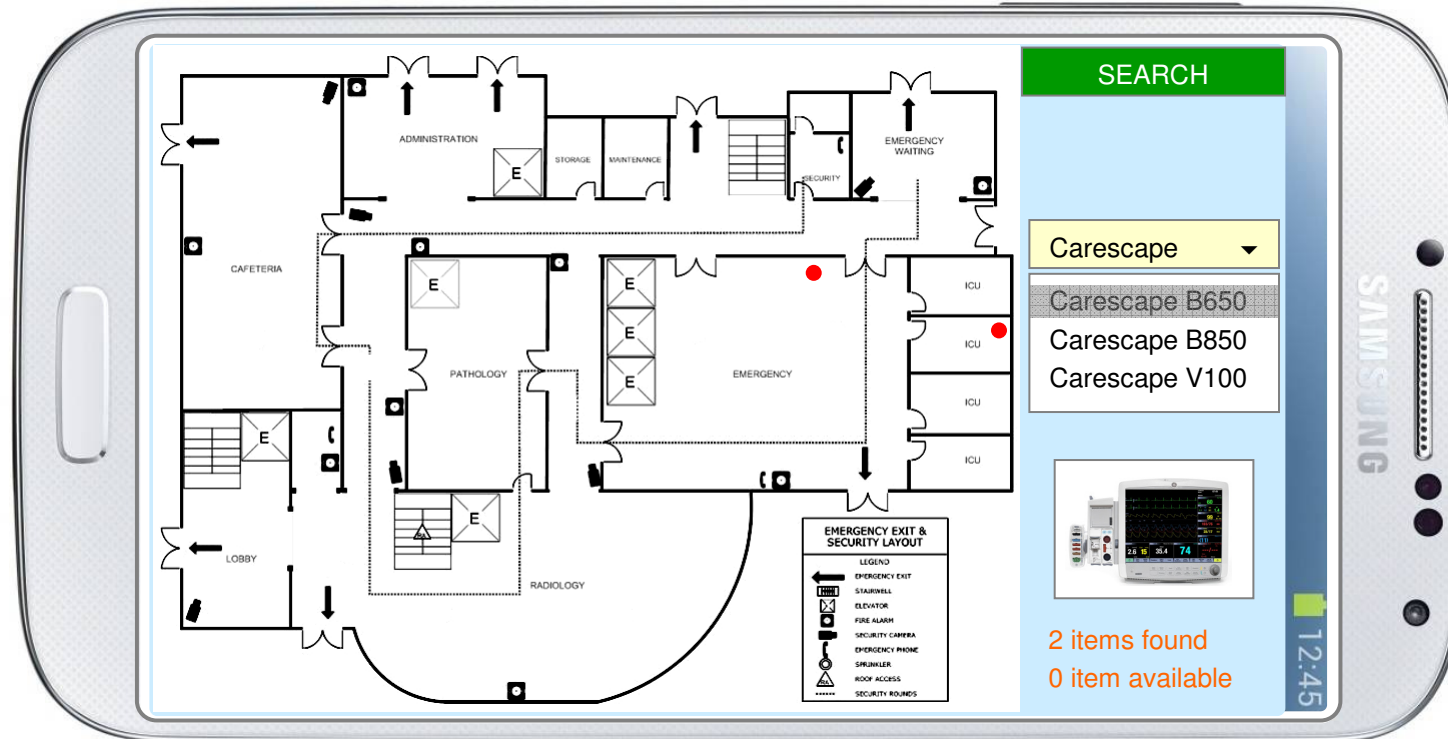
Application Prototype



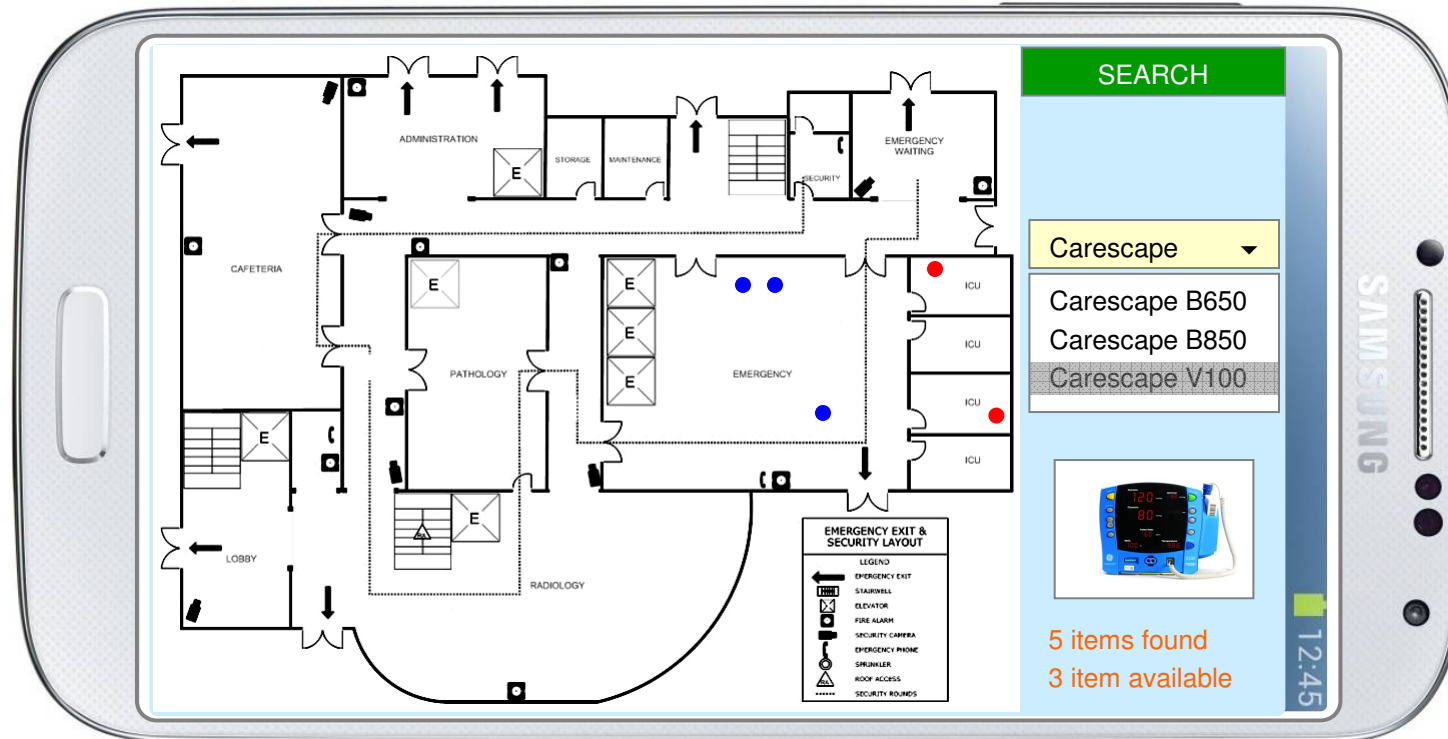
Application Prototype



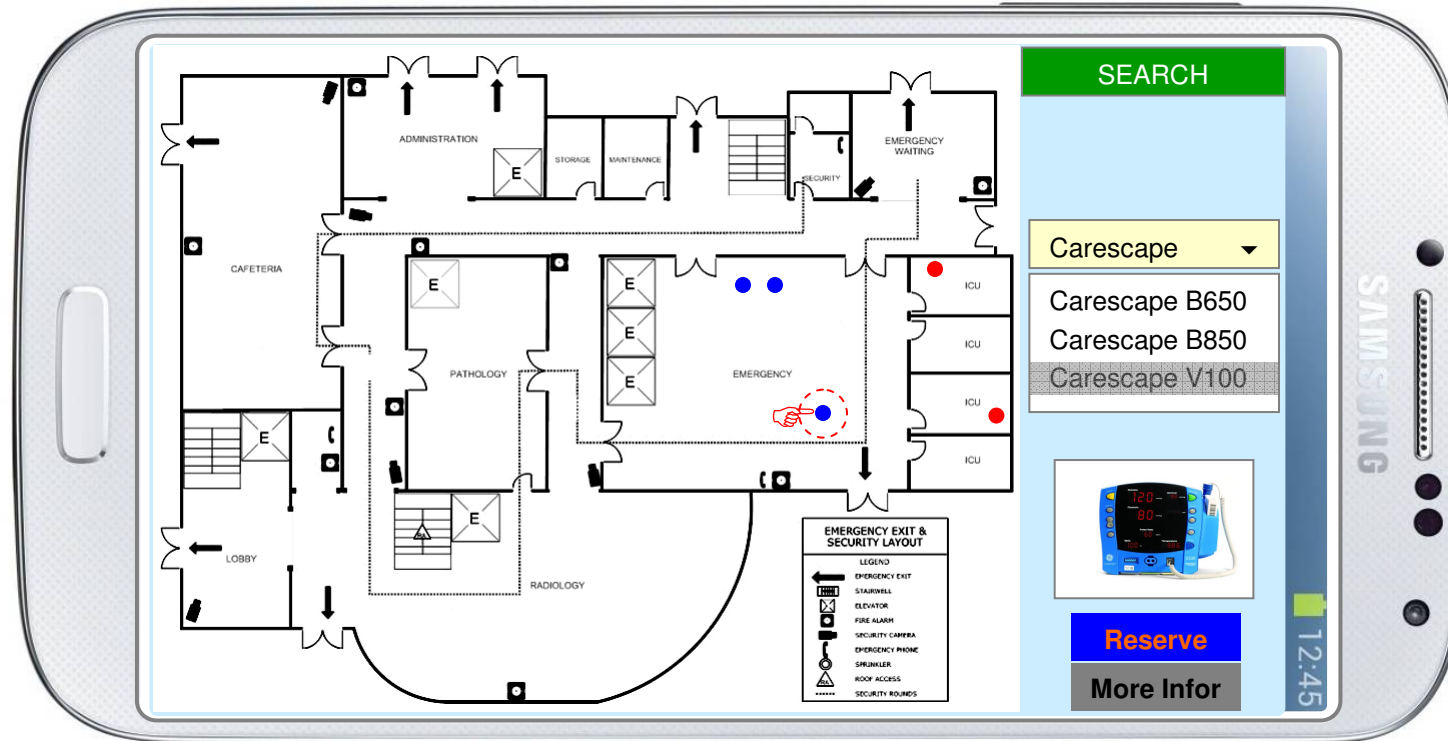
Application Prototype



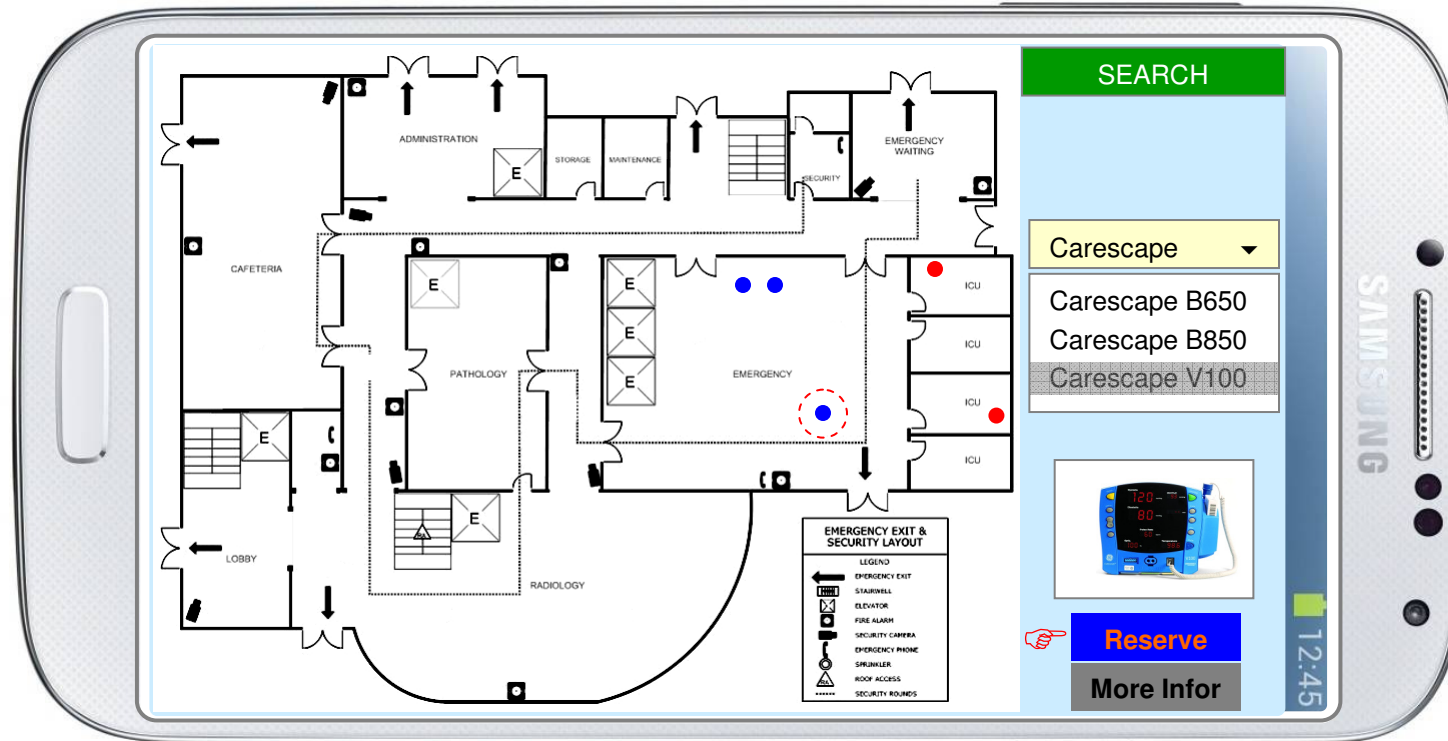
Application Prototype



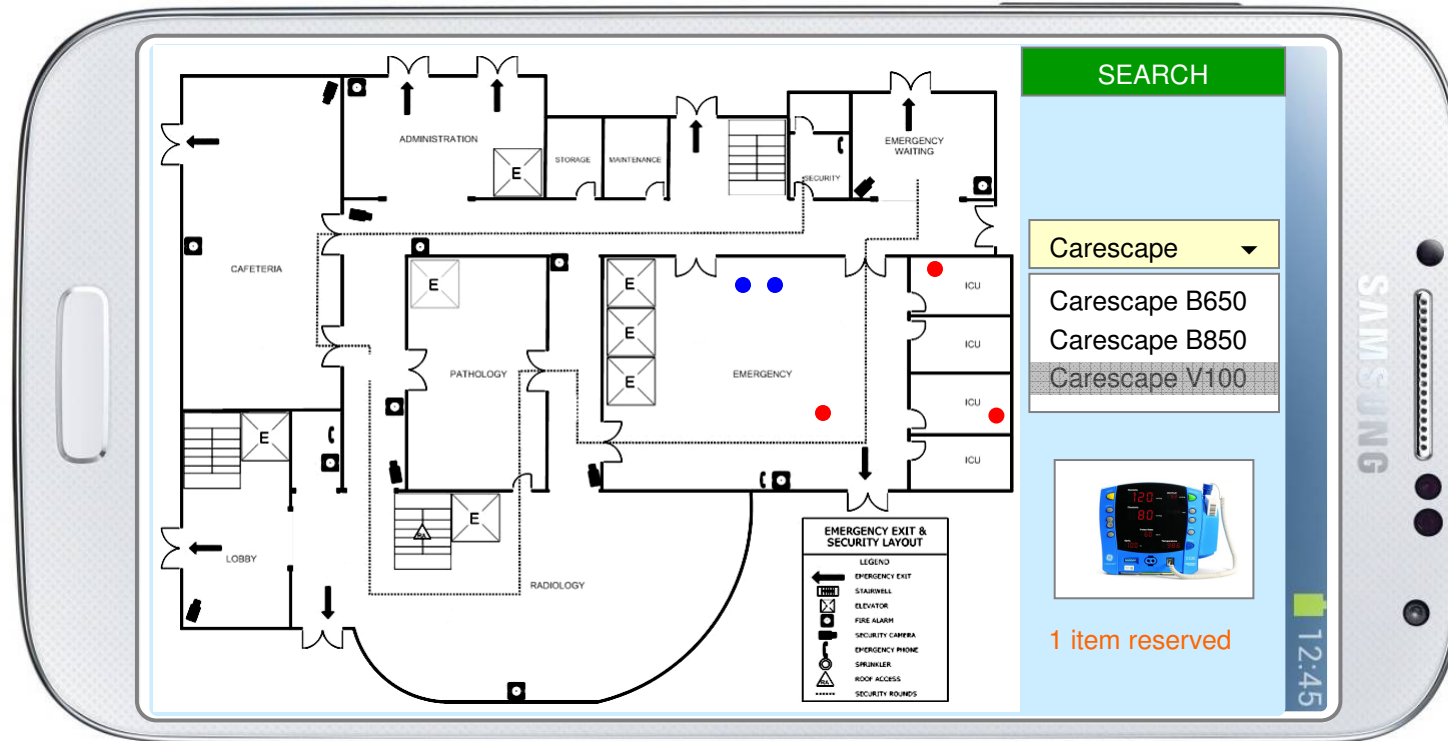
Application Prototype



Application Prototype



Application Prototype





On-going Research

- RTLS technologies
 - Ultra-WideBand (UWB)
 - IEEE 802.11 WiFi
 - RFID
 - etc.
- Choosing the right RTLS
 - **Accuracy:** how close an estimated position is from the true position
 - **Easy of deployment:** cabling installation requirements, disruption to normal operations, ...
 - **Costs:** hardware (tags, receivers, servers), software (location engines, user applications, user interfaces), installation, maintenance, ...



On-going Research

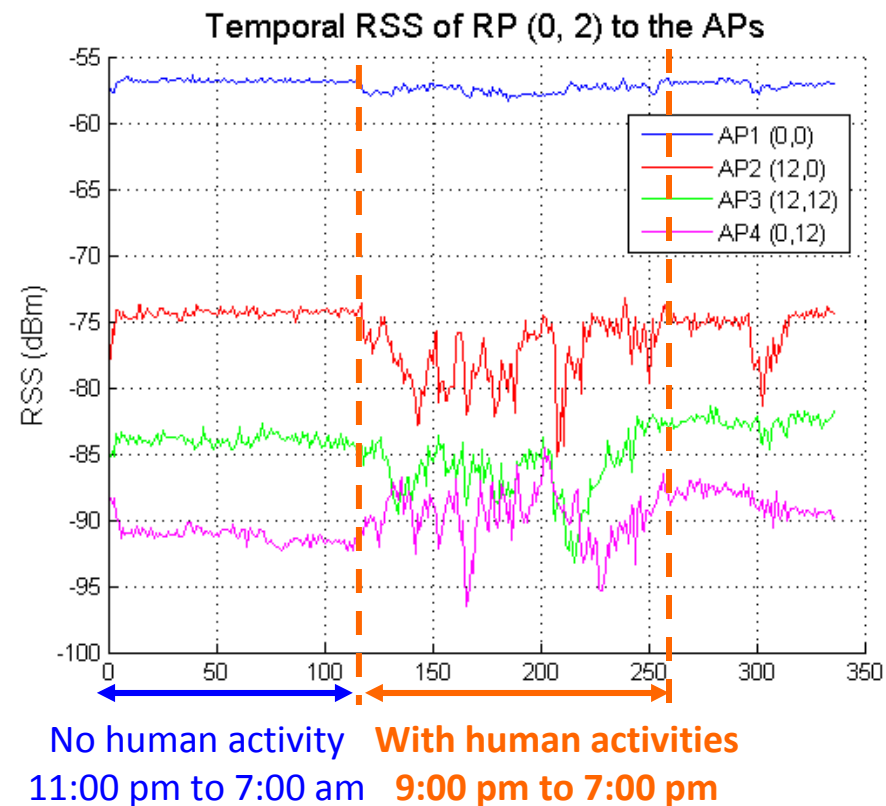
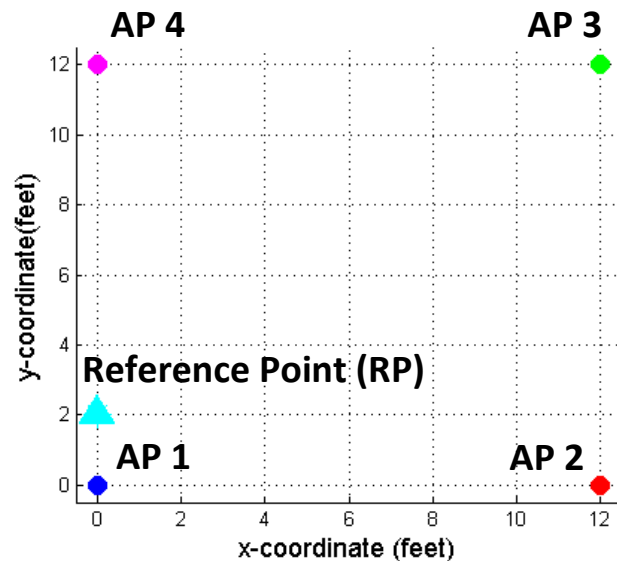
	WiFi	UWB
Typical Accuracy	X Relatively low 1 – 5 m	✓ High 30 cm – 1m
Cost	✓ Low <ul style="list-style-type: none">• Making use of existing Wi-Fi access points	X High <ul style="list-style-type: none">• Deployment of relatively uncommon UWB receivers
Interference Level	X High <ul style="list-style-type: none">• Unlicensed spectrum shared with many other protocols operating at the same spectrum• Relatively vulnerable to multipath fading	✓ Low <ul style="list-style-type: none">• Unlicensed spectrum but with considerably less competitors• Relatively immunity to multipath fading if LOS exists
Tag	✓ Readily available <ul style="list-style-type: none">• Many targeted devices for tracking have built in Wi-Fi (e.g. phones, tablets, etc.)	X Extra deployment <ul style="list-style-type: none">• Need special UWB tags
Ranging Techniques	RSSI and TDOA	AOA, TDOA and TOA



On-going Research

Observations of WiFi RSS through experiments

- RSS may not vary proportionally with Euclidean distance
- RSS can be significantly distorted by day time activities
- RSS within 2 feet to AP tend to have small fluctuation





On-going Research

- **Environmental variations**, which cause the signals to change from time to time even at the same location, present a **challenging task** for WiFi-based RTLS
- Developing techniques **to adapt the temporal radio maps** for indoor location estimation by off-setting environmental variations using data mining techniques
- Investigate the affects of **density and placement of APs and RPs** to the accuracy of estimation



**THANK YOU
VERY MUCH**

**(We have various posters & real-life system
demonstrations in the Poster/Demo Session)**