Mobile Patient Monitoring: Designing the Transition from Sensors and Displays to Decision Support Tools

Matthias Görges

mgorges@cw.bc.ca

Departments of Electrical and Computer Engineering and Anesthesiology, Pharmacology & Therapeutics
The University of British Columbia, Vancouver, Canada

Tricorder

io.com

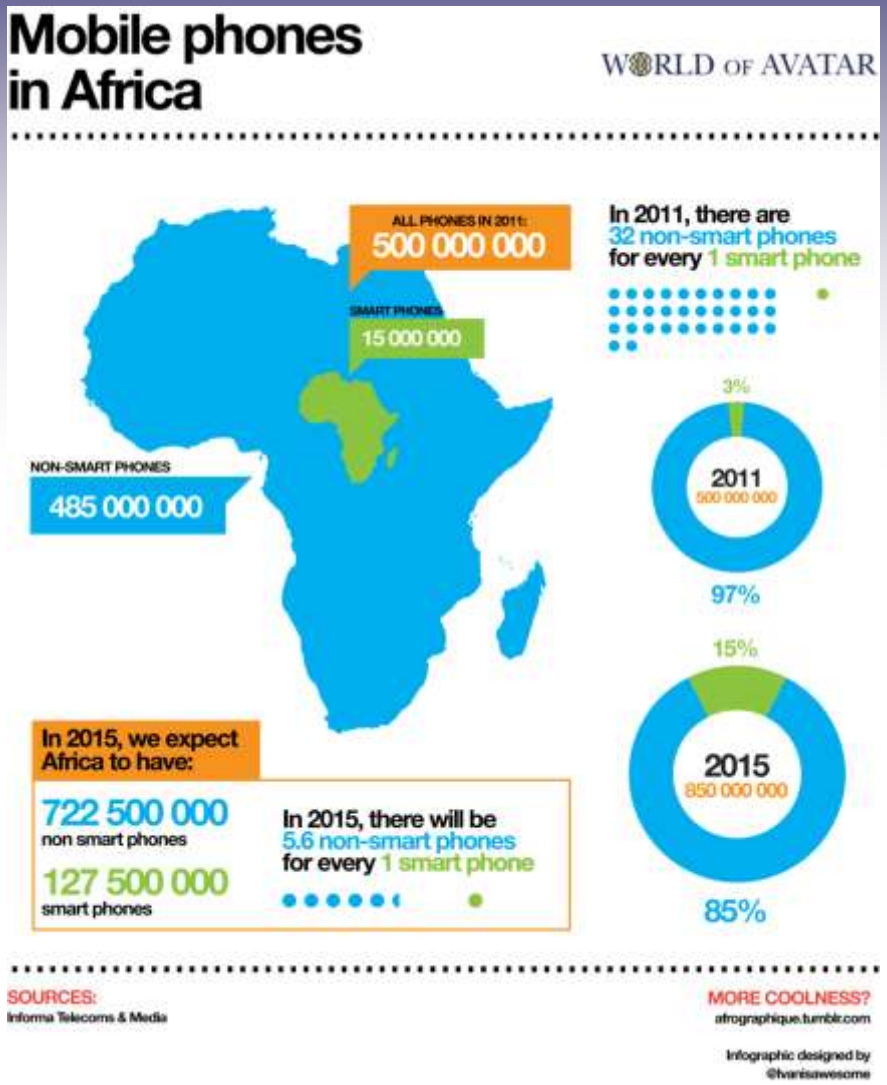
Outline

- Motivation
- Sensors & Displays
- Infrastructure & Software Development
- Applications:
  - Team Communication
  - Decision Support
- Future work?

Outline

- Motivation
- Sensors & Displays
- Infrastructure & Software Development
- Applications:
  - Team Communication
  - Decision Support
- Future work?

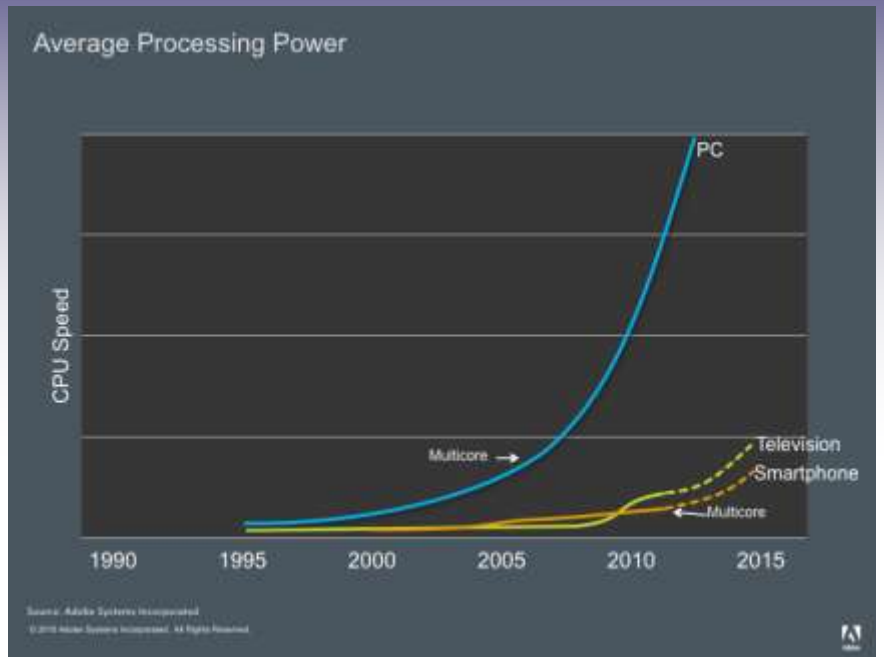
Ubiquity of smart phones

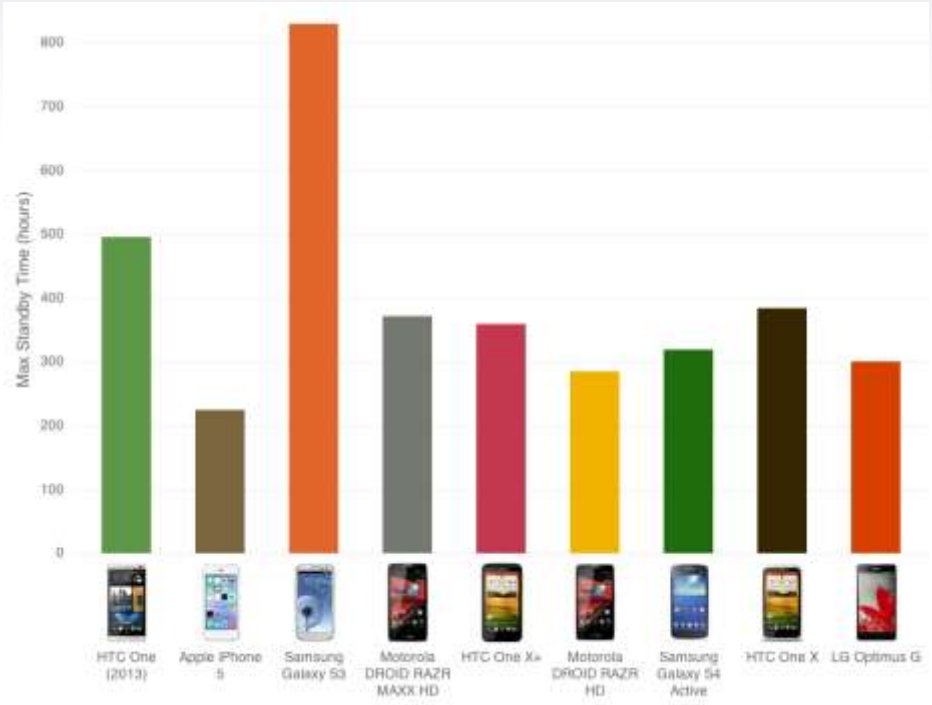


Ugandan charging station

Indian farmer

Processing / Power

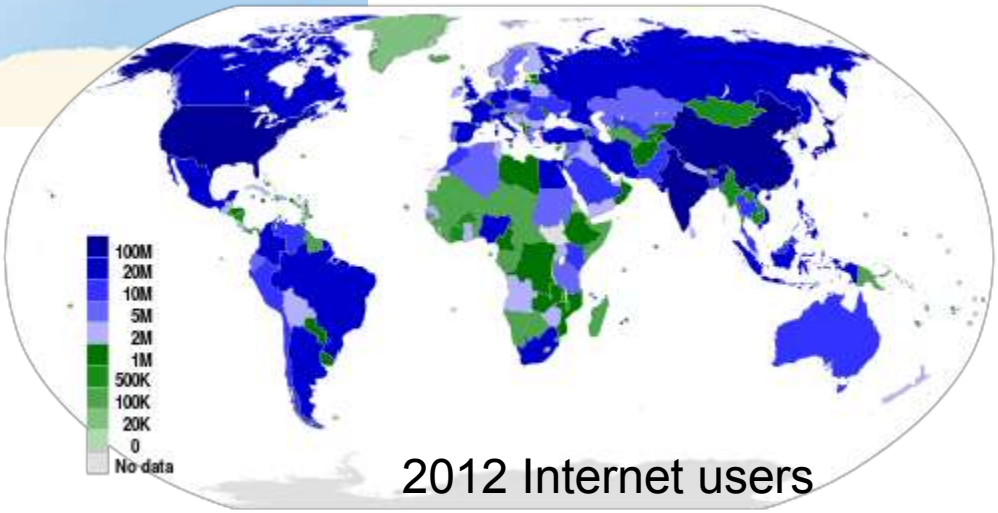




adobe.com, time.com

Connectivity

2009 Cellphone coverage



2012 Internet users

globaltelesat.co.uk, wikipedia.org

Outline

- Motivation
- Sensors & Displays
- Infrastructure & Software Development
- Applications:
  - Team Communication
  - Decision Support
- Future work?

SpO2

masimo.com, lgtmedical.com, samsung.com

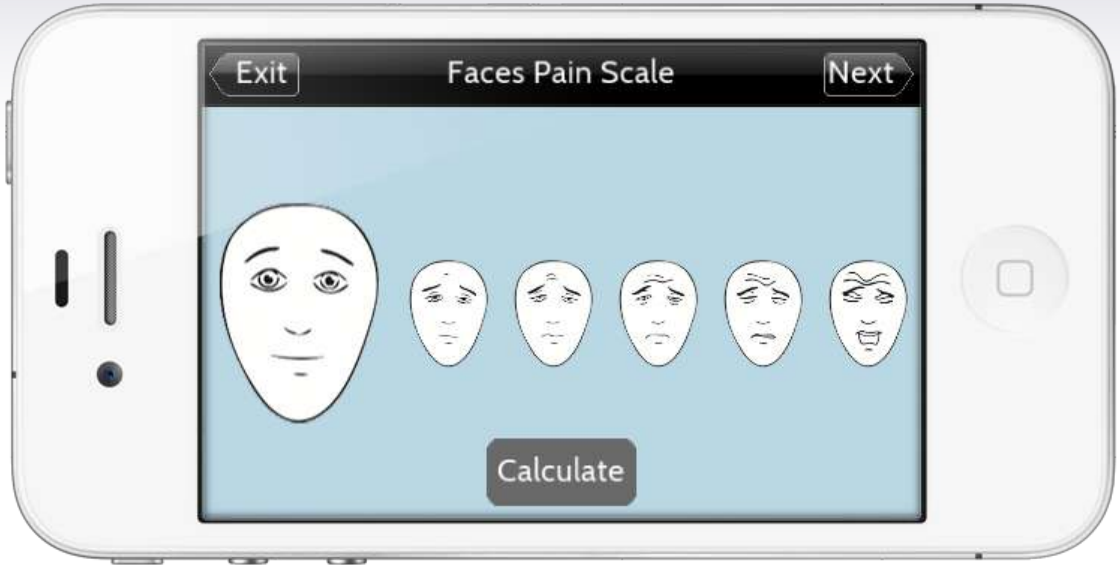
Temperature, NIBP, Glucose

icelsius.com, withings.com, sanofi.com

Health: weight, steps, sleep

fitbit.com, apple.com, tractivity.com

Surveys, Questionnaires



part.cfri.ca

Outline

- Motivation
- Sensors & Displays
- Infrastructure & Software Development
- Applications:
  - Team Communication
  - Decision Support
- Future work?

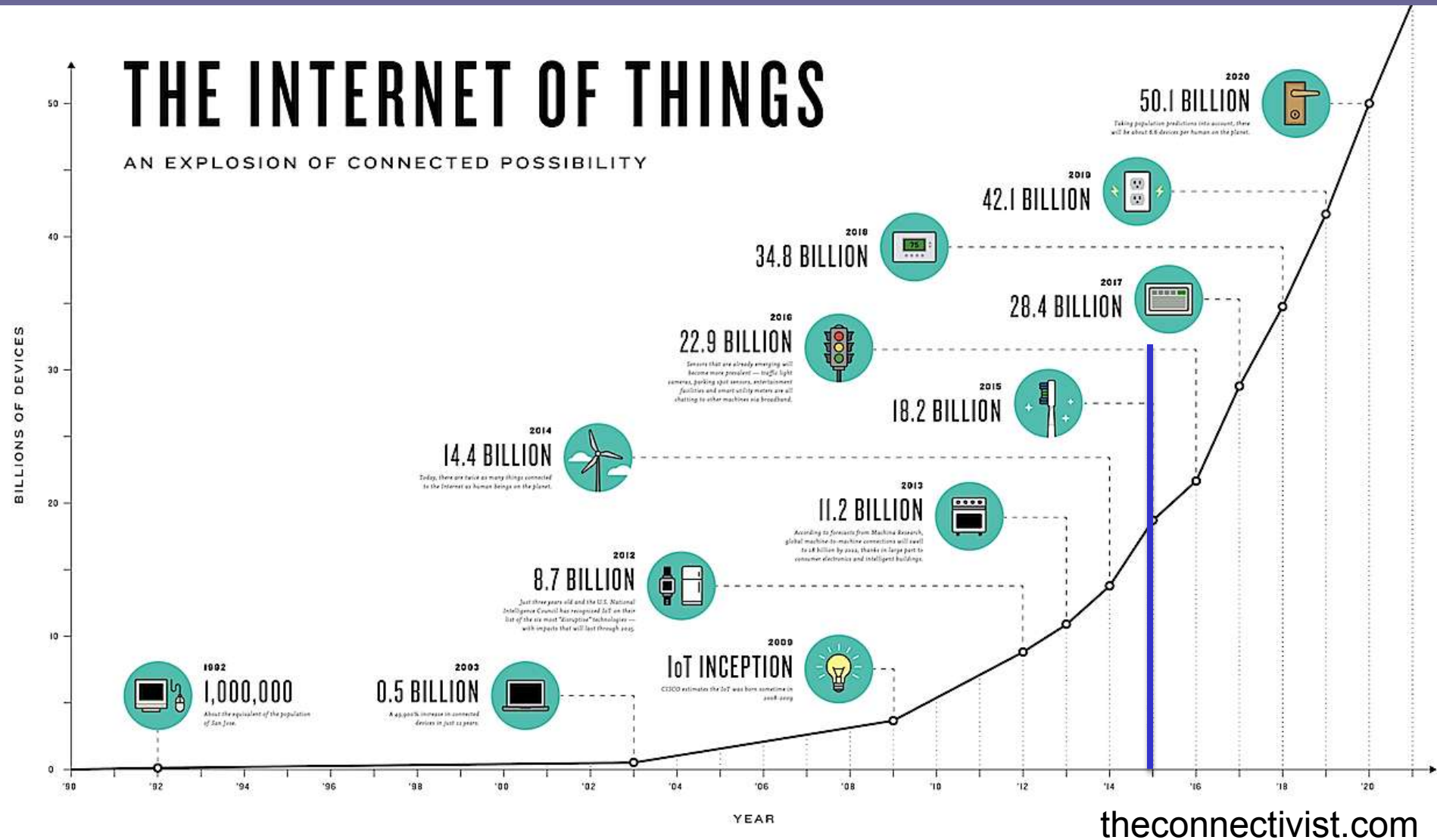
Connectivity

- Mode
  - Bluetooth Low Energy
  - WLAN/802.11
  - GSM/3G

  → In the end they'll all speak IPv6

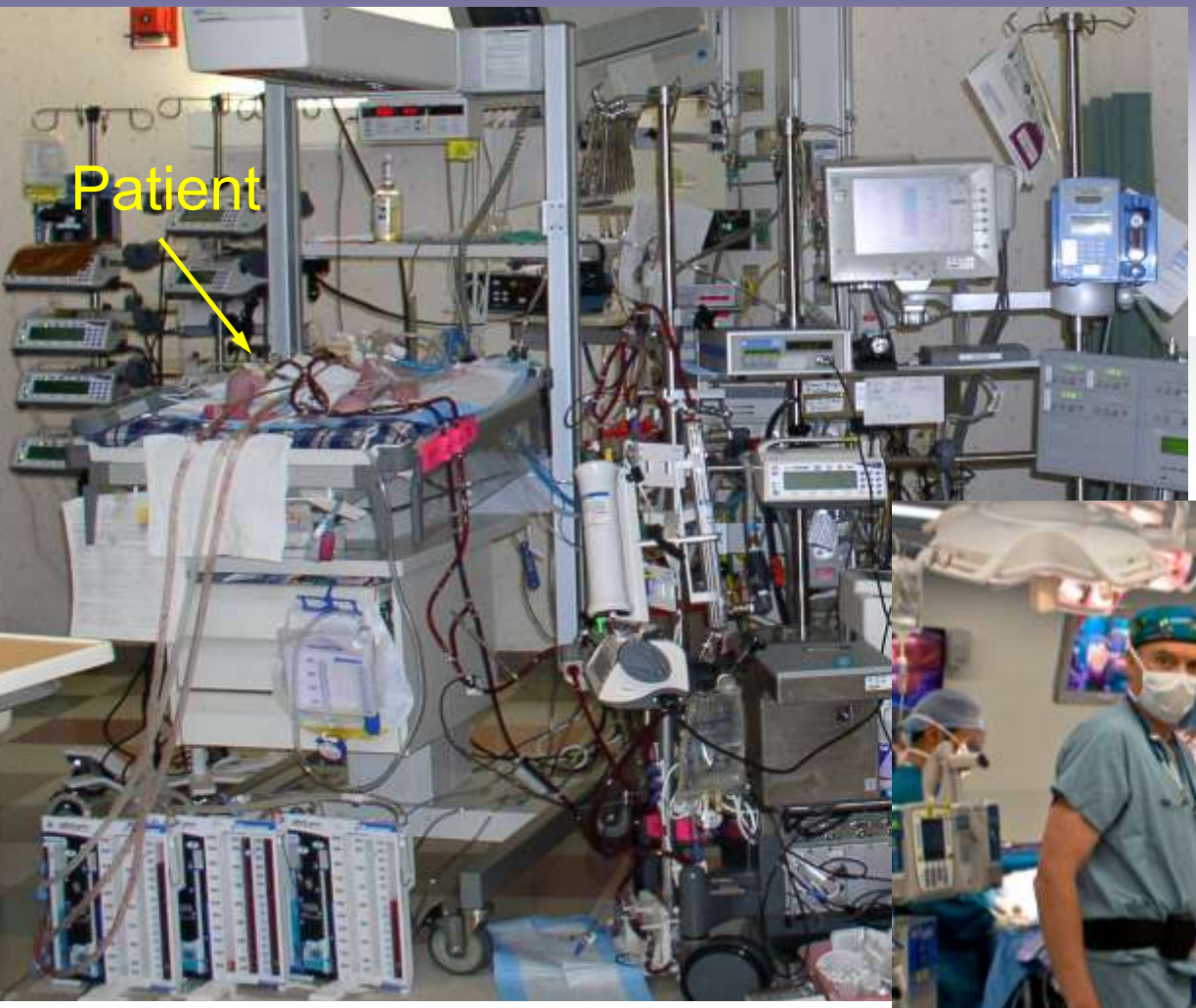
- Considerations
  - Power consumption
  - Range / Interference
  - Transmission speed

IoT growth



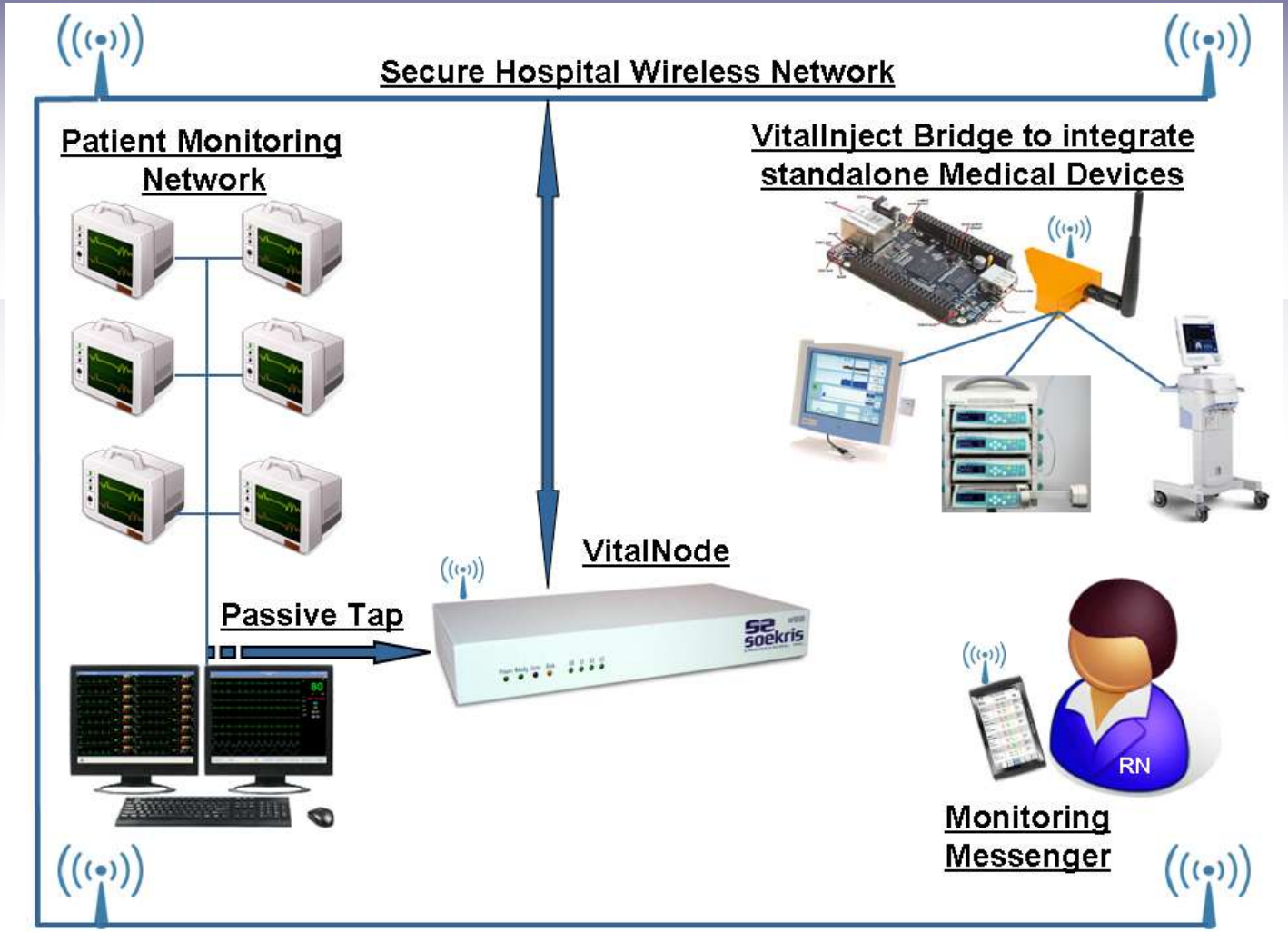
theconnectivist.com

Lack of connectivity



University of Utah NICU&BMI program
BC Children's Hospital/CFRI

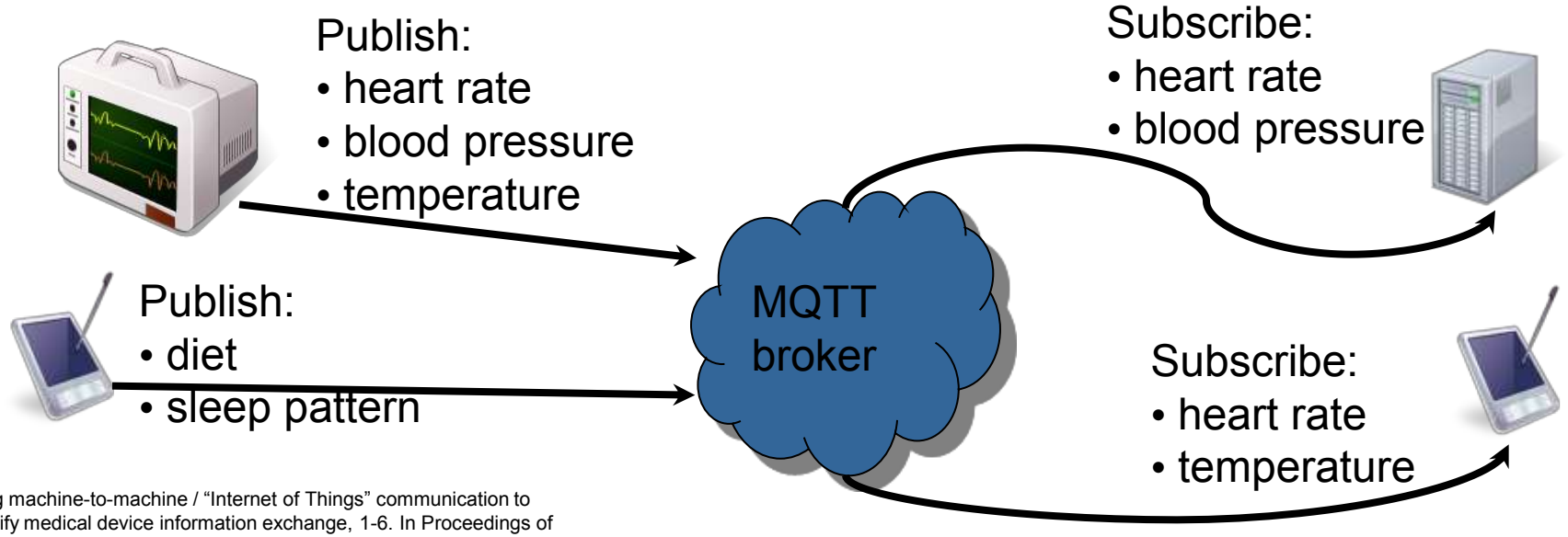
Data Integration



Using machine-to-machine / “Internet of Things” communication to simplify medical device information exchange, 1-6. In Proceedings of the 4th International Conference on the Internet of Things (IoT 2014).

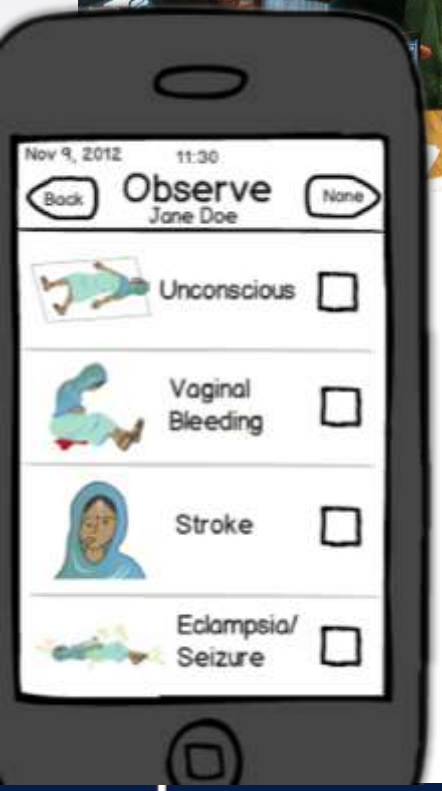
Data broker

- IoT standards: MQTT (Mosquitto)
  - Free, open, lean, simple, scalable (Facebook)
  - Encryption with OpenSSL
- Messages are not transmitted directly to receiver
  - Instead published as "Topics"
  - Subscribers express interest in topics (subscription)
  - Quality of service (get/send exactly once, maybe once)



Using machine-to-machine / "Internet of Things" communication to simplify medical device information exchange, 1-6. In Proceedings of the 4th International Conference on the Internet of Things (IoT 2014).

mHealth Development Process



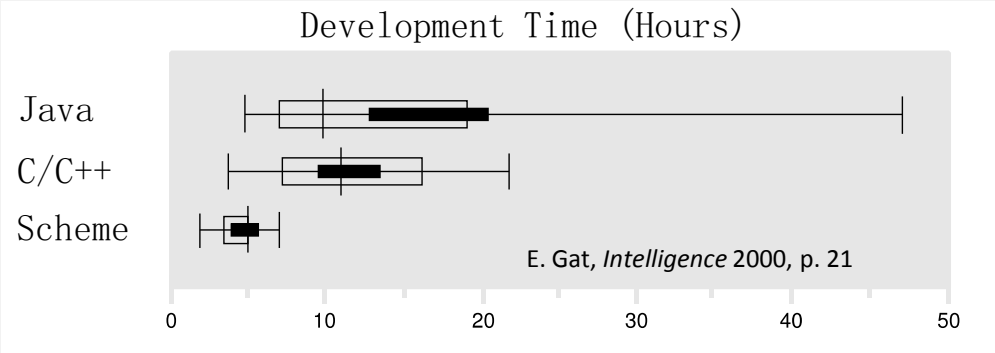
Design

Coding

Test / Usability

LambdaNative

- Higher productivity
- Smaller code base
  - Easier to maintain
- Modular
- Portable
- Simple C integration



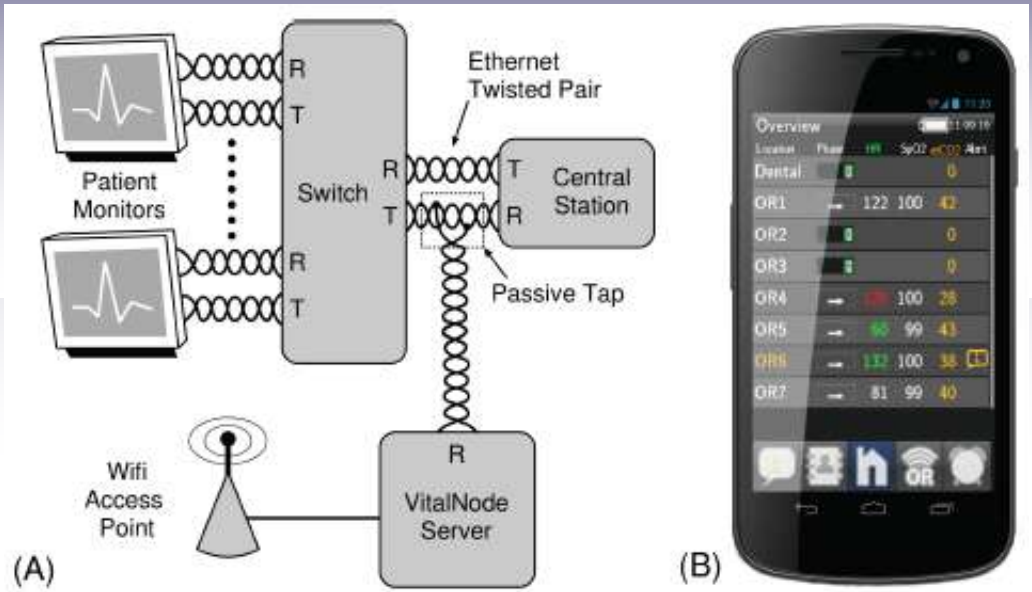
Mobile	Desktop	Embedded
iOS	OS X	OpenWrt
Android	Linux	OpenBSD
BlackBerry	Windows	

open source

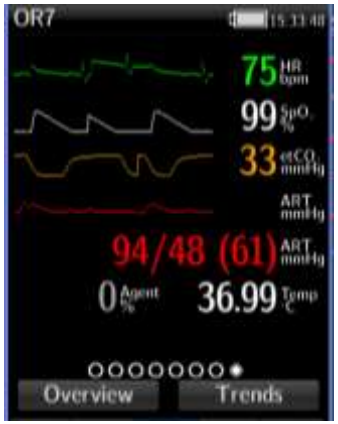
Outline

- Motivation
- Sensors & Displays
- Infrastructure & Software Development
- Applications:
  - Team Communication
  - Decision Support
- Future work?

Mobile Monitoring: telePORT



SNAPSHOT

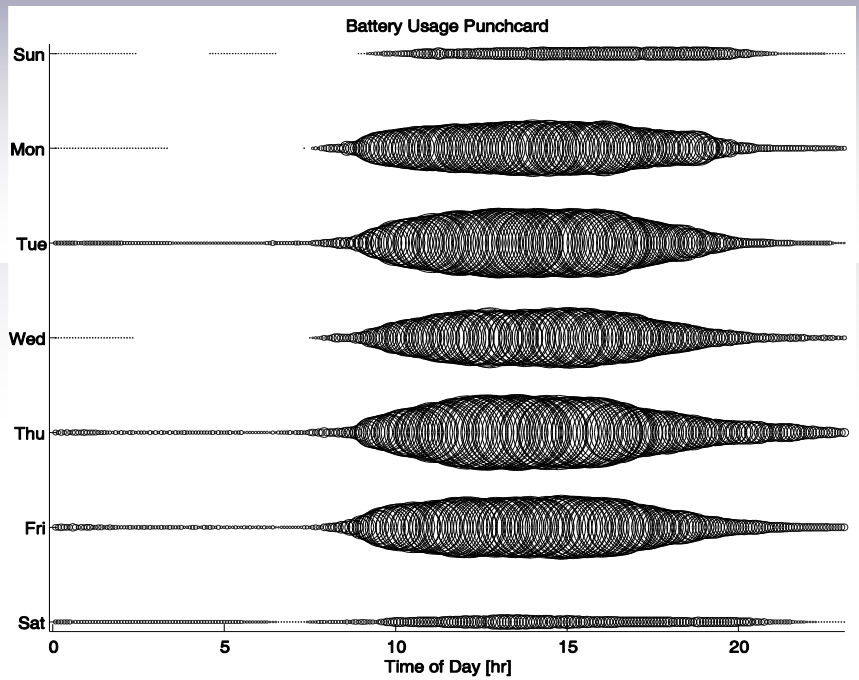


Anesth Analg. 2011;112(5S):S207

telePORT: Usage

System Utilization:

- Battery drain as a surrogate
- Peaks 11-15h on weekdays



Frequently used functions

- Messaging (30%), Overview (20%), Pages/Alerts (19%), and Waveforms (14%)

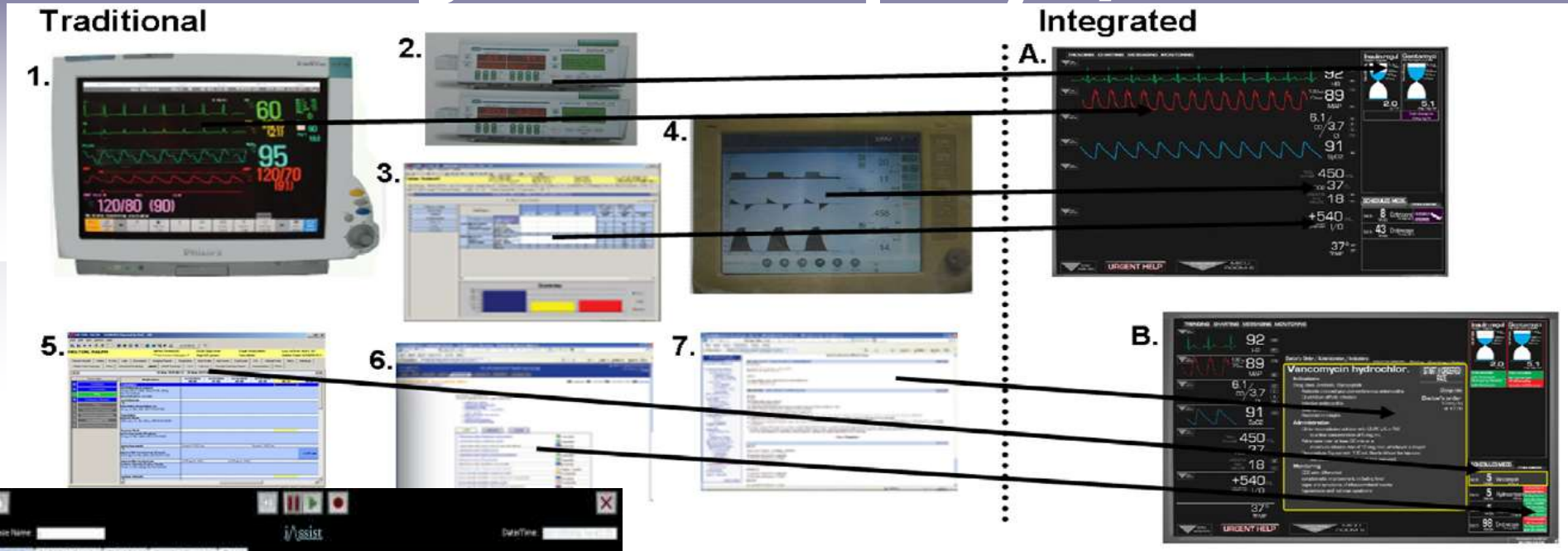
Paging and Messaging:

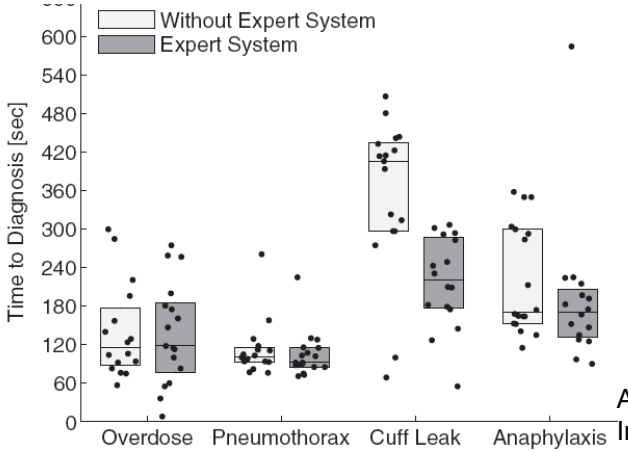
- Average 5.3 pages/day
  - Majority between 8-10h and 11-14h
- Average 1.1 messages /day
  - Five pairs of the nine users

Biggest problem/limitation:

- Infrastructure
- Battery life

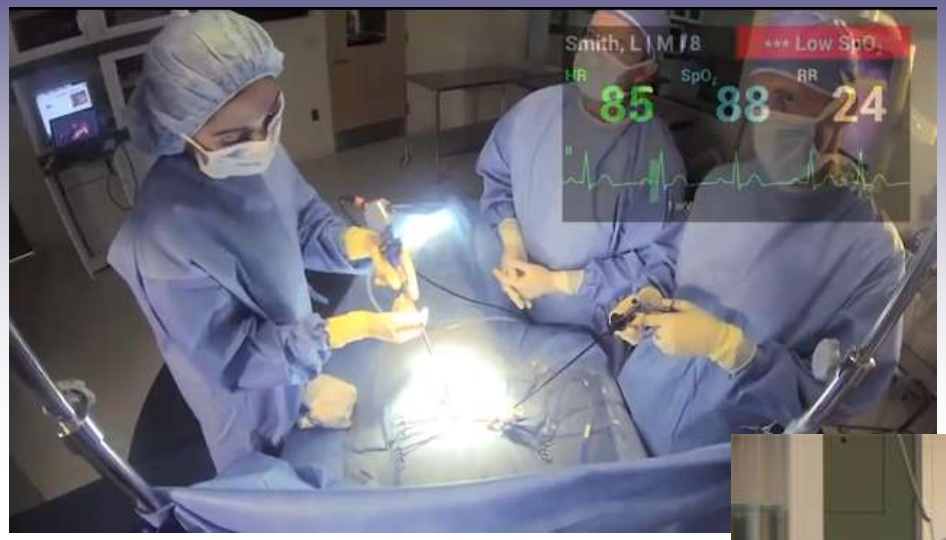
Integrated displays/DSS





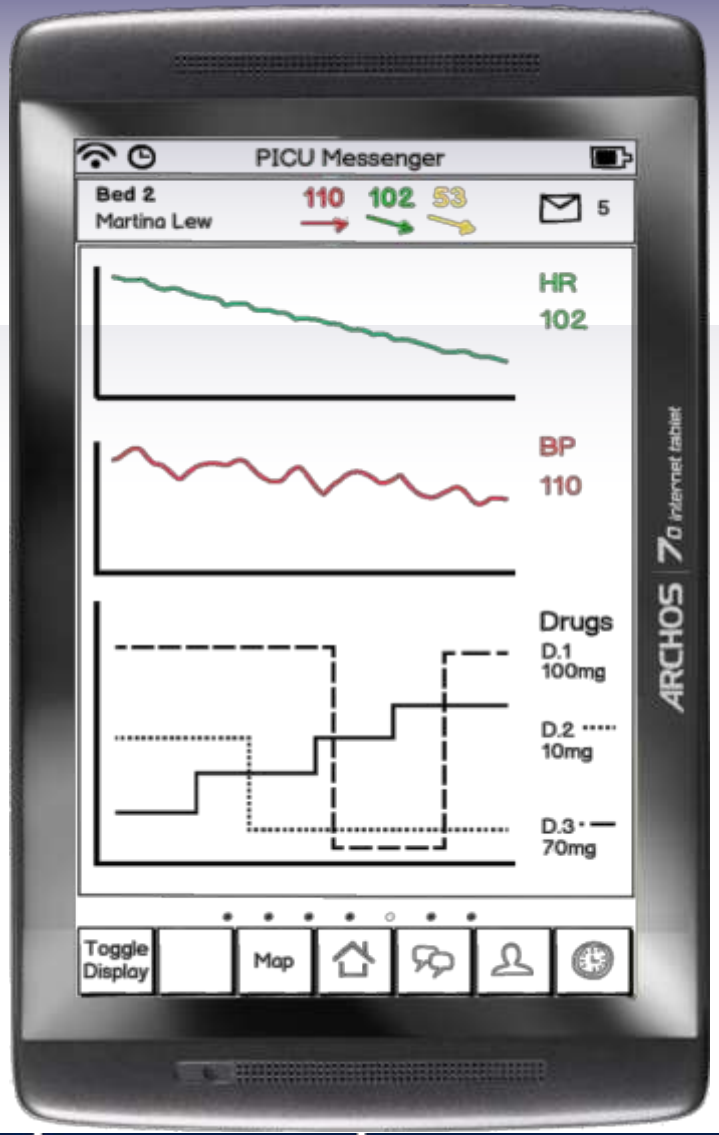
Anesth Analg. 2013 Aug;117(2):380–91.
Int J Med Inform. 2013 Aug;82(8):665–75

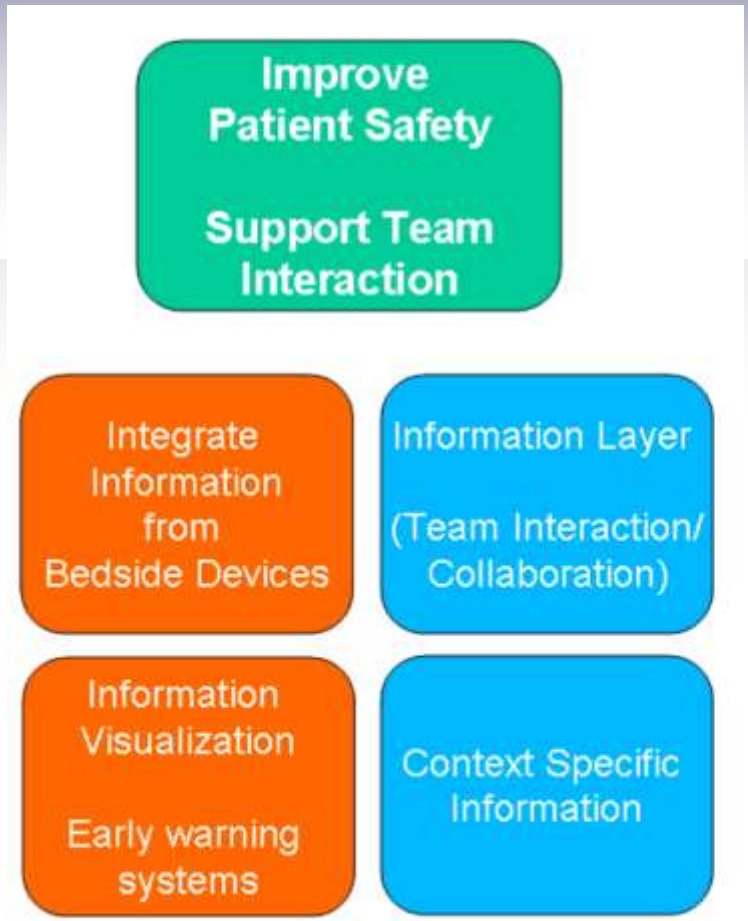
Google Glass – HMD



accenture.com, qualcomm.com

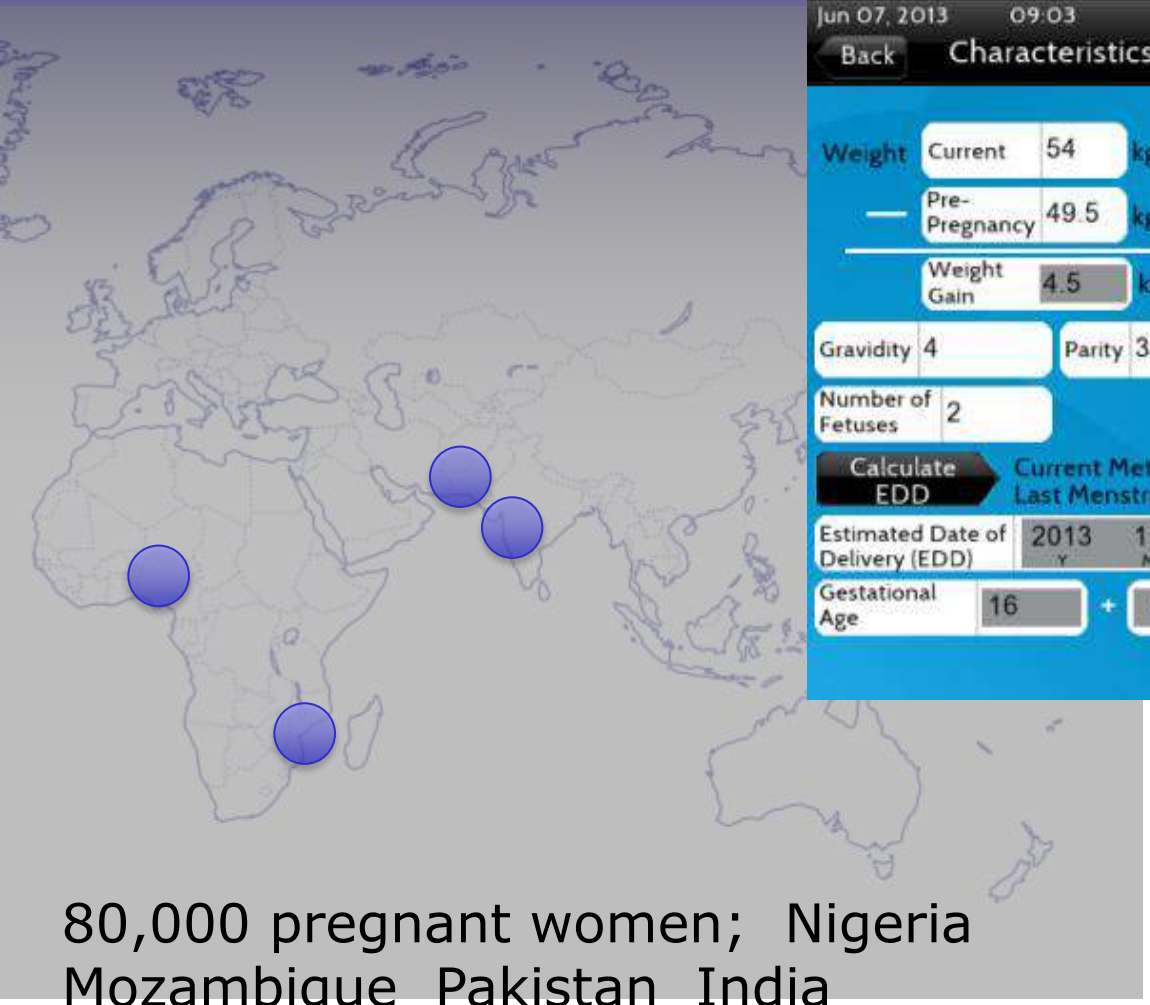
VitalPAD





Mobile Patient Monitoring for the Pediatric Intensive Care Unit: Work Domain Analysis and Rapid Prototyping Results, 3765-70. In 2013 IEEE International Conference on Systems, Man, and Cybernetics.

POTM / CLIP



80,000 pregnant women; Nigeria Mozambique Pakistan India

IEEE Journal of Biomedical and Health Informatics 18 (6) p. 1857-64

POTM / miniPIERS

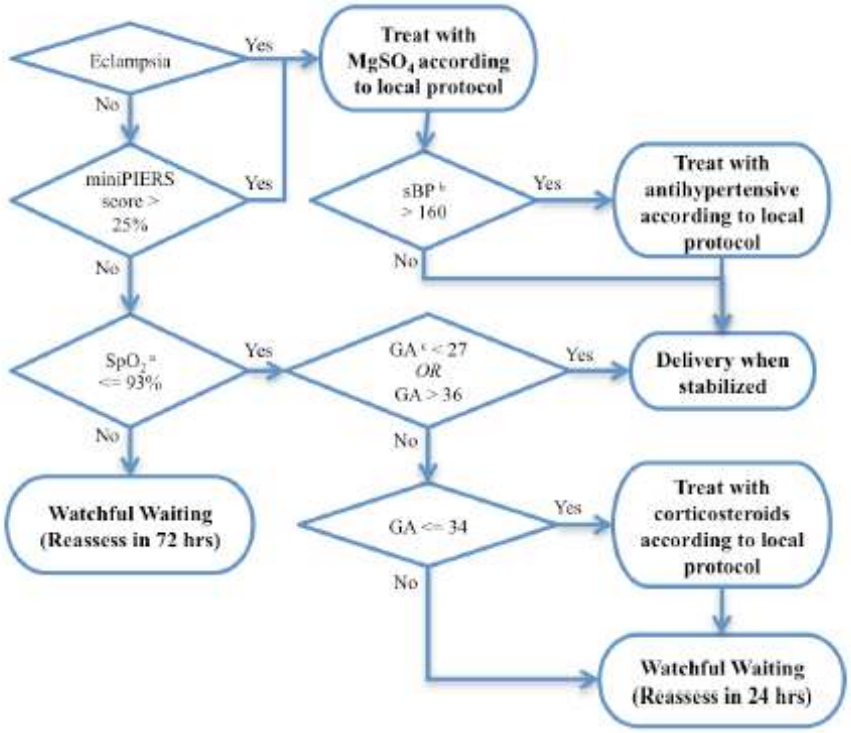
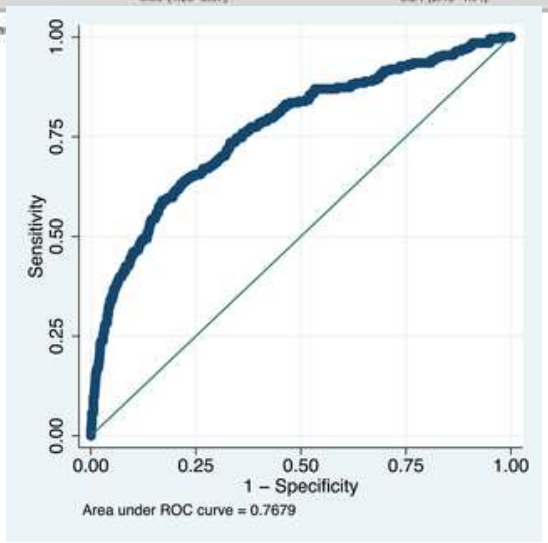


Fig. 1. A simplified diagram of the decision tree for a pregnant woman who is not in labour and is eligible for the POTM clinical study.

Candidate Predictor	Univariate OR (95% CI)	Multivariate OR (95% CI)
Demographics		
Maternal age (years)	0.99 [0.97–1.01]	n/a
Gestational age at admission (wk)	0.95 [0.92–0.98]	0.34 [0.11–1.11][a]
Parity (multiparous versus primiparous)	0.73 [0.57–0.95]	0.74 [0.56–0.99]
Signs		
Systolic BP (mmHg)	1.02 [1.01–1.02]	3.89 [1.19–12.66][a]
Diastolic BP (mmHg)	1.03 [1.02–1.03]	n/a
Dipstick proteinuria		
2+	1.44 [0.99–2.09]	0.80 [0.51–1.27]
3+	2.88 [2.07–4.00]	1.53 [0.99–2.37]
4+	3.23 [2.18–4.85]	1.67 [0.96–2.88]
Symptoms		
Headache	3.42 [2.58–4.52]	1.53 [1.07–2.17]
Visual disturbances	2.63 [2.00–3.45]	
Chest pain	6.42 [3.62–11.37]	2.33 [1.38–3.94]
Dyspnoea	6.35 [4.08–9.89]	
Epigastric/right upper quadrant pain	3.93 [2.96–5.21]	n/a
Nausea/vomiting	3.40 [2.53–4.57]	n/a
Abdominal pain with vaginal bleeding	6.03 [4.25–8.57]	3.24 [2.13–4.94]

Variables presented as part of the multivariate a
[a]Log transformed.
OR, odds ratio.
doi:10.1371/journal.pmed.1001589.t003



PLoS Med 11(1): e1001589.

Outline

- Motivation
- Sensors & Displays
- Infrastructure & Software Development
- Applications:
  - Team Communication
  - Decision Support
- Future work?

Future ?

- (Home) health data analytics
- Point of care testing
- IoT data brokers in hospitals
- Electronic health record integration
- More large population, model-based risk stratification tools / apps

- We don’t know yet …

http://part.cfri.ca

http://ecem.ece.ubc.ca

Questions?

Email: mgorges@cw.bc.ca

32