

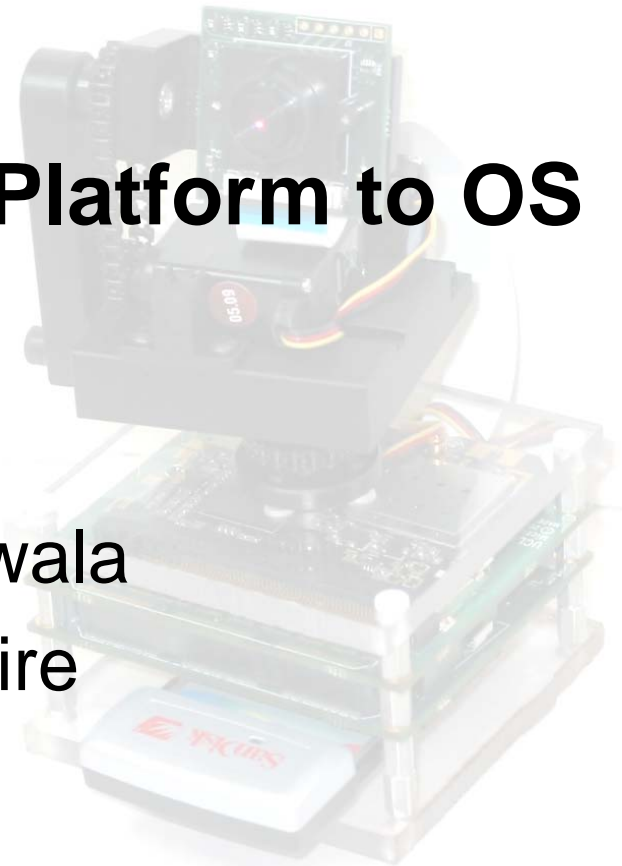


CENTER FOR EMBEDDED NETWORKED SENSING

Green Systems: From Platform to OS

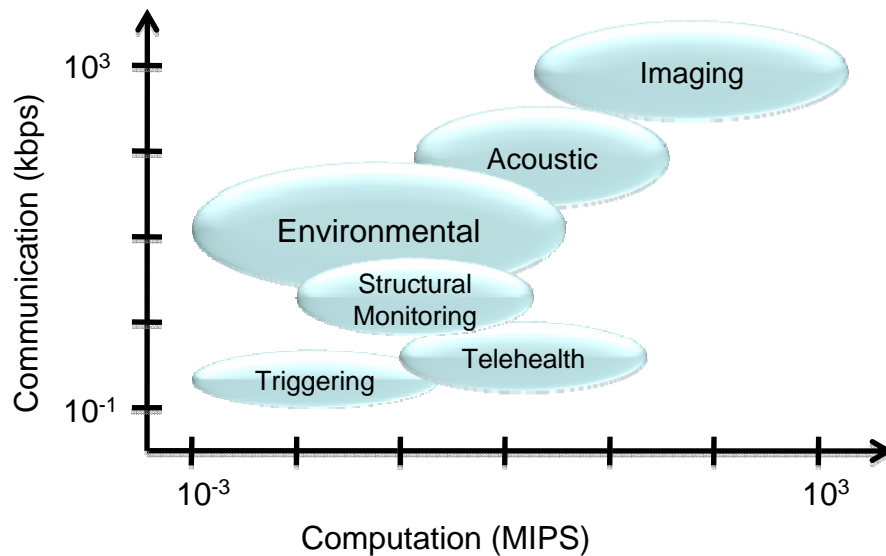


Zainul Charbiwala
Dustin McIntire



Many shades of Green...

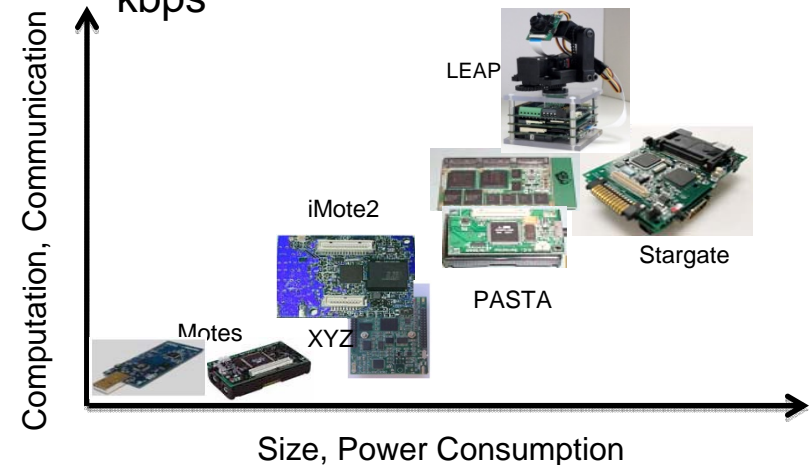
Sensing Application Requirements



- No single processor or radio spans this range efficiently
 - A mix of complementary components is better suited
 - Components arranged in a staged or tiered fashion enable selective activation

- Resource needs of wireless sensor nodes have high dynamic range

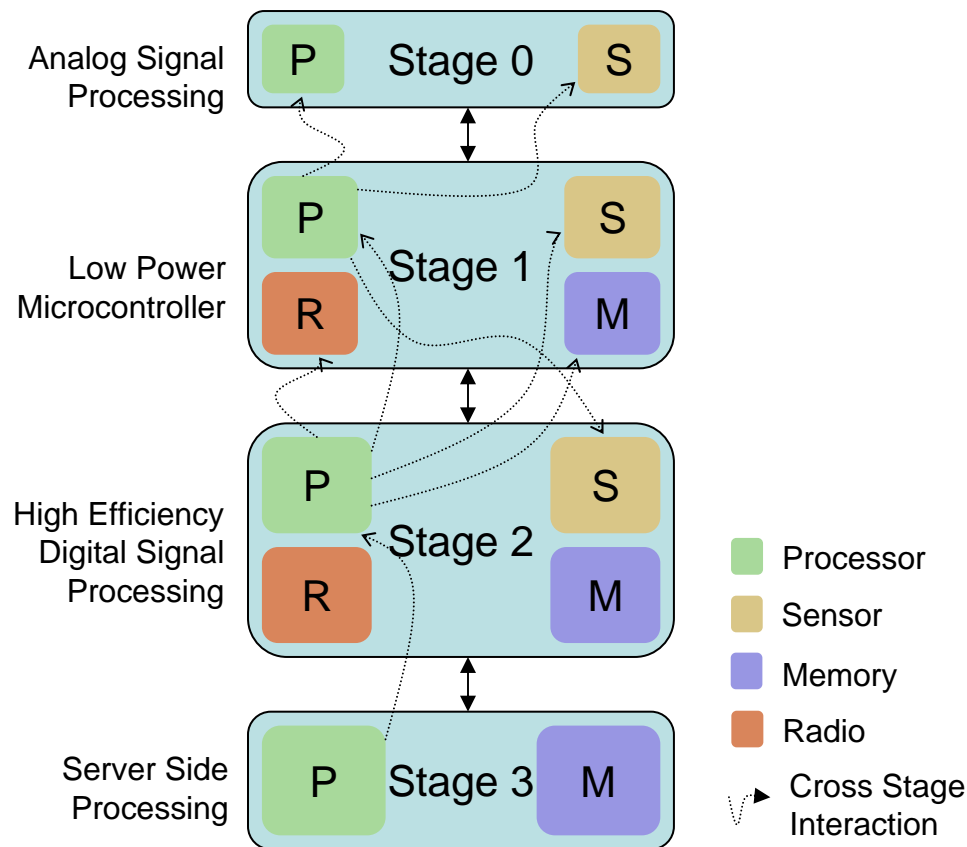
- Sensing tasks require from 10^{-3} to 10^3 MIPS even on the same node
- Communication requirements across nodes range from 10^{-1} to 10^3 kbps



Platform Capabilities and Cost

ASPIRE Staged System

- Stages of complementary components provide high dynamic range of capabilities

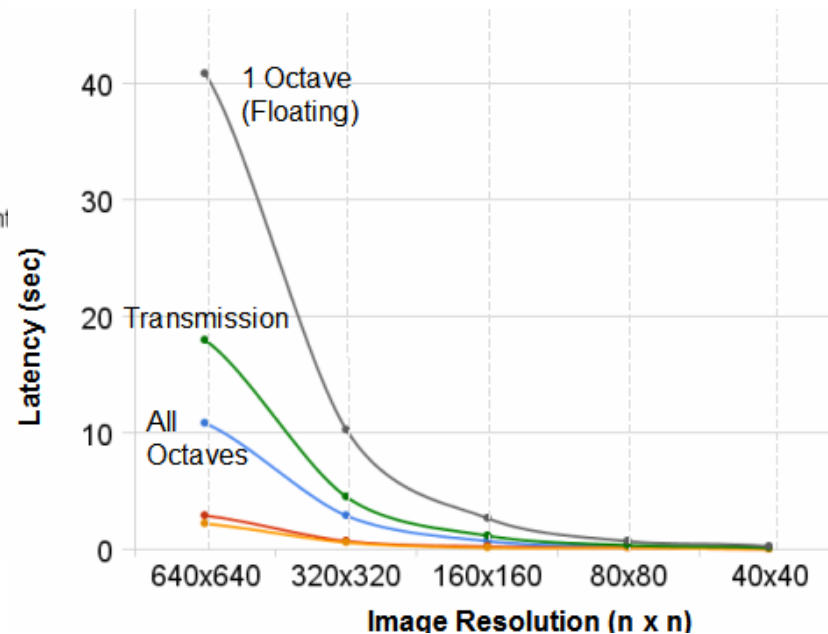
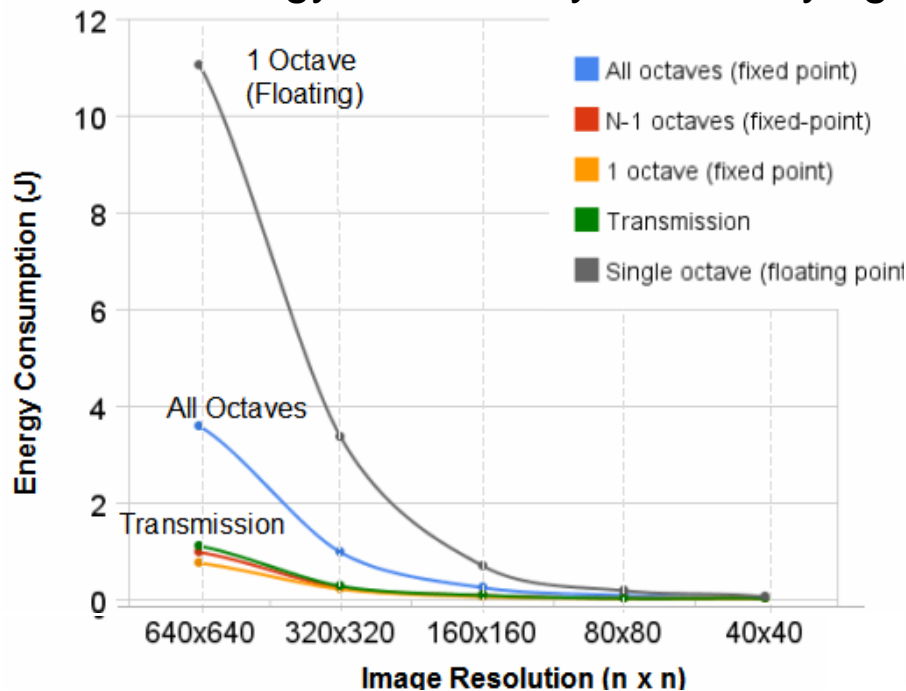


- Staged design raises interesting research issues
 - Optimal stage activation policies based on ‘event context’
 - Interconnect architectures for ‘context transfer’ across stages
 - Lowering transition times between stages exchanging ‘context control’
 - Energy aware resource management at OS level
 - Lowering quiescent power consumption

Exploring Stage Activation Tradeoffs

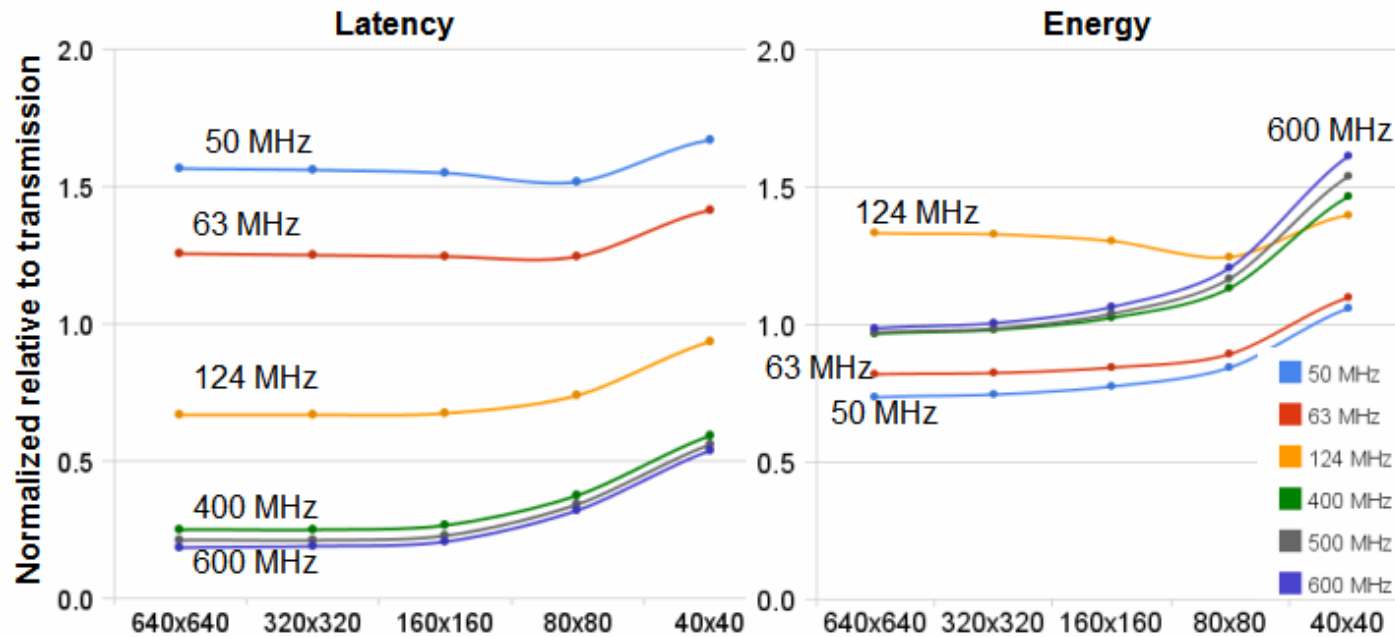
- In an image sensing application, should object recognition be performed on Stage 2 or Stage 3
 - Some results applying SIFT on a Blackfin DSP for Stage 2 and transmitting raw image over radio for Stage 3

Energy and latency when varying arithmetic precision and # of octaves



Exploring Stage Activation Tradeoffs

Energy and latency when varying CPU frequency
(Normalized with respect to transmission)

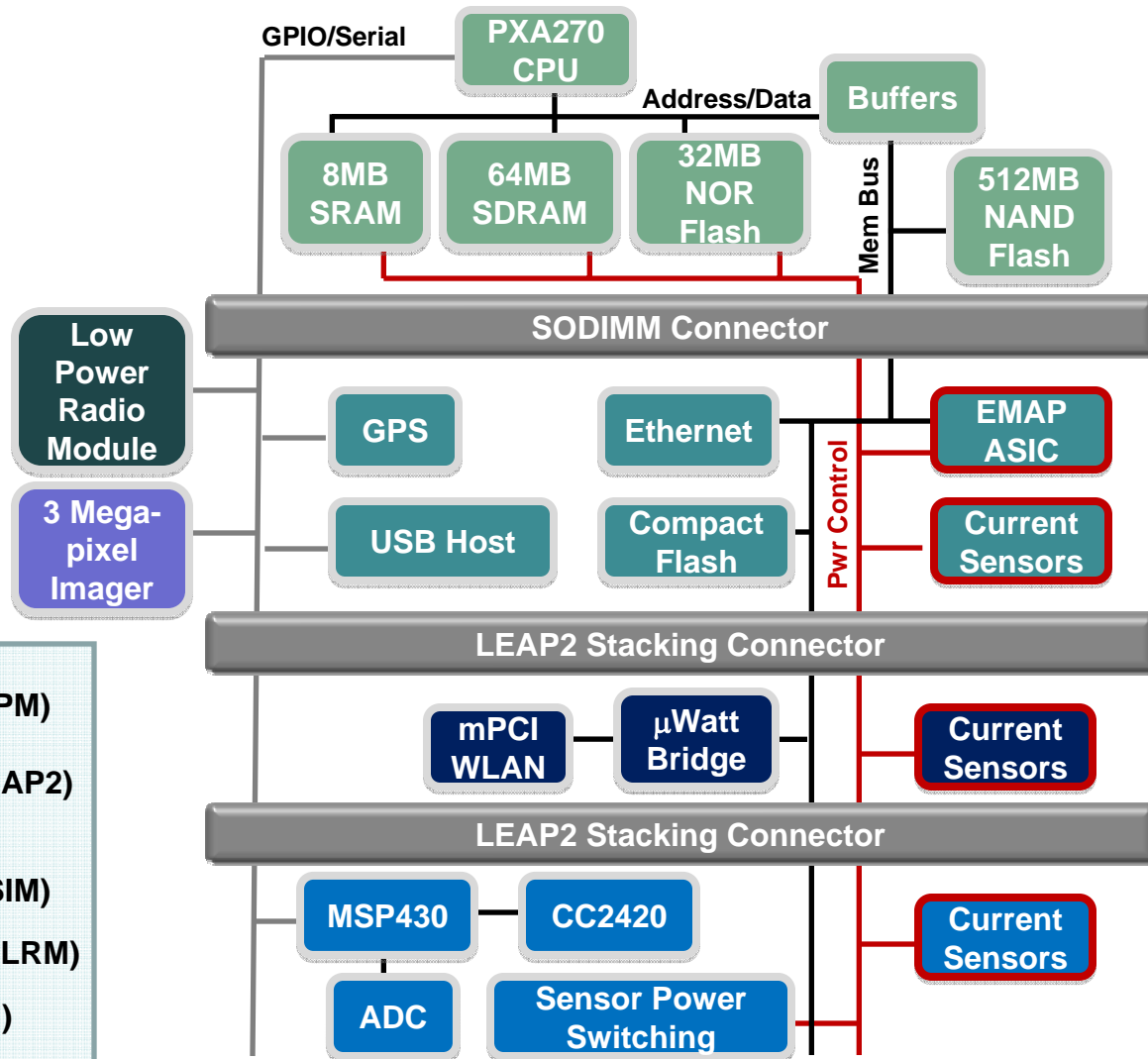
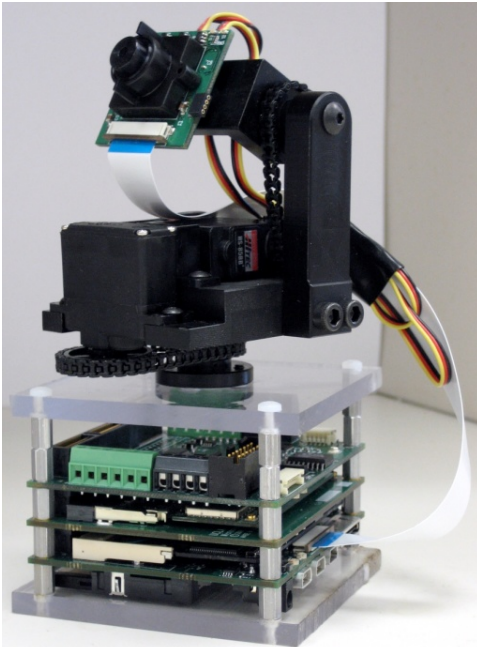








Teresa Ko, Zainul M. Charbiwala, Shaun Ahmadian, Mohammad Rahimi, Mani B. Srivastava, Stefano Soatto, Deborah Estrin, "Exploring Tradeoffs in Accuracy, Energy and Latency of SIFT in Wireless Camera Networks," *Proceedings of the First ACM/IEEE International Conference on Distributed Smart Cameras (ICDSC-07)*.



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Energy Aware Platforms - LEAP



-  Host Processor Module (HPM)
-  Energy Management and Accounting Processor (EMAP2)
-  Mini PCI Module (MPM)
-  Sensor Interface Module (SIM)
-  Low Power Radio Module (LRM)
-  CMOS Imager Module (CIM)



etop - Per Process Energy Accounting

Based on well-known "top" Unix program

Real-time display of per-subsystem current/power/energy consumption

etop - 03:57:25 up 3:57, 2 users, load average: 0.17, 0.17, 0.17
 Tasks: 26 total, 1 running, 25 sleeping, 0 stopped, 0 zombie
 Cpu(s): 2.3%us, 4.0%sy, 0.0%ni, 93.7%id, 0.0%wa, 0.0%hi, 0.0%si, 0.0%st
 Mem: 62768k total, 17636k used, 45132k free, 364k buffers
 Swap: 0k total, 0k used, 0k free, 0k cached

Channel	Amps	Power	Energy	Time
00(Ethernet):	116.47 mA	384.36 mW		
01(Imager):	0.88 mA	2.90 mW		
02(Radio):	0.19 mA	0.61 mW		
03(GPS):	0.17 mA	0.57 mW	8.08 J	14192 sec
04(USB):	0.44 mA	1.44 mW	20.14 J	14192 sec
05(CF):	0.18 mA	0.60 mW	8.47 J	14192 sec
06(HPM):	86.61 mA	433.04 mW	5984.21 J	14192 sec
07(Vin):	2.43 V	0.00		
08(SDRAM):	12.72 mA	22.89 mW		
09(NOR):	0.15 mA	0.27 mW		
10(SRAM):	0.91 mA	1.64 mW		
11(PXA):	13.67 mA	19.87 mW		
12(NAND):	0.22 mA	0.72 mW		
13(Vmem):	1.81 V	0.00		
14(Vcore):	1.45 V	0.00		
15(Vio):	3.00 V	0.00		

116mA, 384mW

SDRAM: 12.72mA
SRAM: 0.91mA

PID	USER	PR	NI	S	%CPU	%MEM	TIME+	ENERGY	COMMAND
9812	root	15	0	R	1.0	1.6	0:02.46	0.42(0.20/0.22)	etop
9795	root	15	0	S	0.0	2.1	0:00.10	0.17(0.05/0.12)	bash
9784	root	15	0	S	0.3	3.1	0:00.56	0.16(0.04/0.12)	sshd
693	root	17	0	S	0.0	0.9	0:00.00	0.14(0.00/0.09)	dhclient
840	root	18	0	S	0.0	1.5	0:00.02	0.14(0.00/0.12)	sshd
750	root	17	0	S	0.0	1.2	0:00.27	0.13(0.00/0.10)	syslog-ng
226	root	20	-4	S	0.0	0.7	0:00.47	0.13(0.00/0.11)	udev
218	root	35	10	S	0.0	0.0	0:00.00	0.11(0.00/0.10)	jffs2_gcd_mtd4
178	root	35	10	S	0.0	0.0	0:00.19	0.11(0.00/0.11)	jffs2_gcd_mtd3
829	root	25	0	S	0.0	0.9	0:00.03	0.10(0.00/0.08)	inetd
10336	root	19	0	S	0.7	0.8	0:00.02	0.10(0.00/0.08)	sleep
9612	root	19	0	S	0.0	1.6	0:00.05	0.10(0.00/0.09)	measure.sh
762	rpc	25	0	S	0.0	0.0	0:00.00	0.00(0.00/0.00)	rpcbind
853	root	15	0	S	0.0	2.0	0:00.00	0.00(0.00/0.00)	sshd
1	root	15	0	S	0.0	0.0	0:00.00	0.00(0.00/0.00)	init
130	root	21	0	S	0.0	0.0	0:00.00	0.00(0.00/0.00)	sshd
4	root	10	-5	S	0.0	0.0	0:00.00	0.00(0.00/0.00)	sshd
3	root	10	-5	S	0.0	0.0	0:00.00	0.00(0.00/0.00)	sshd
2	root	34	19	S	0.0	0.0	0:00.00	0.00(0.00/0.00)	sshd
5	root	10	-5	S	0.0	0.0	0:00.00	0.00(0.00/0.00)	sshd
35	root	13	-5	S	0.0	0.0	0:00.00	0.00(0.00/0.00)	sshd
51	root	25	0	S	0.0	0.0	0:00.00	0.00(0.00/0.00)	sshd
52	root	15	0	S	0.0	0.0	0:00.00	0.00(0.00/0.00)	sshd
53	root	20	-5	S	0.0	0.0	0:00.00	0.00(0.00/0.00)	sshd
54	root	20	-5	S	0.0	0.0	0:00.00	0.00(0.00/0.00)	sshd
331	root	11	-5	S	0.0	0.0	0:00.00	0.00(0.00/0.00)	sshd

bash:
0.05 Joules in user mode
0.12 Joules in kernel mode
Total energy consumption while process was running: 0.17 J

Real-time display of per-process energy consumption

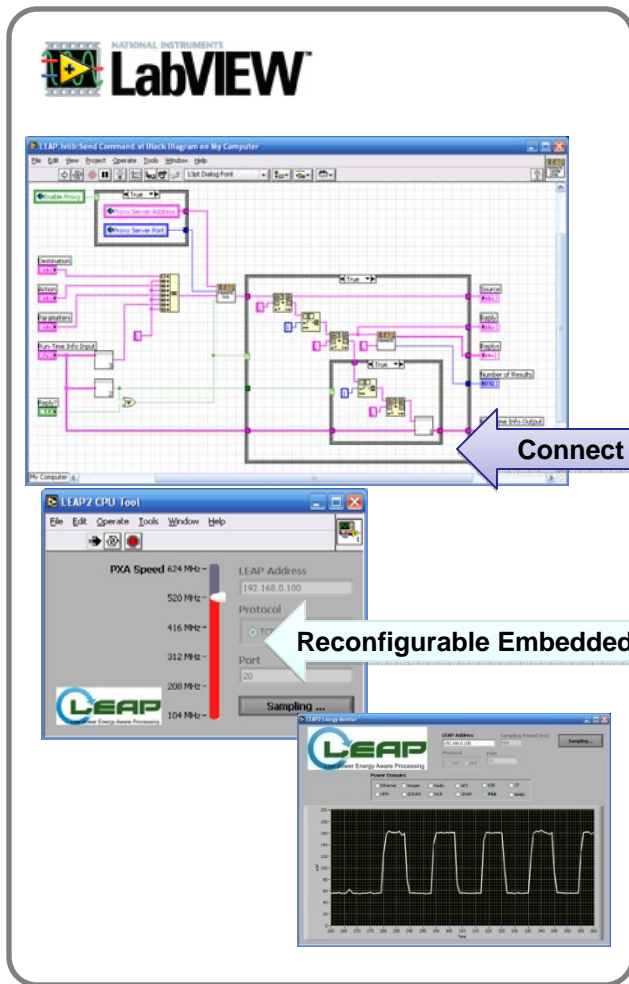
Scheduler modifications: measure consumption during system/user time

•Thanos Stathopoulos

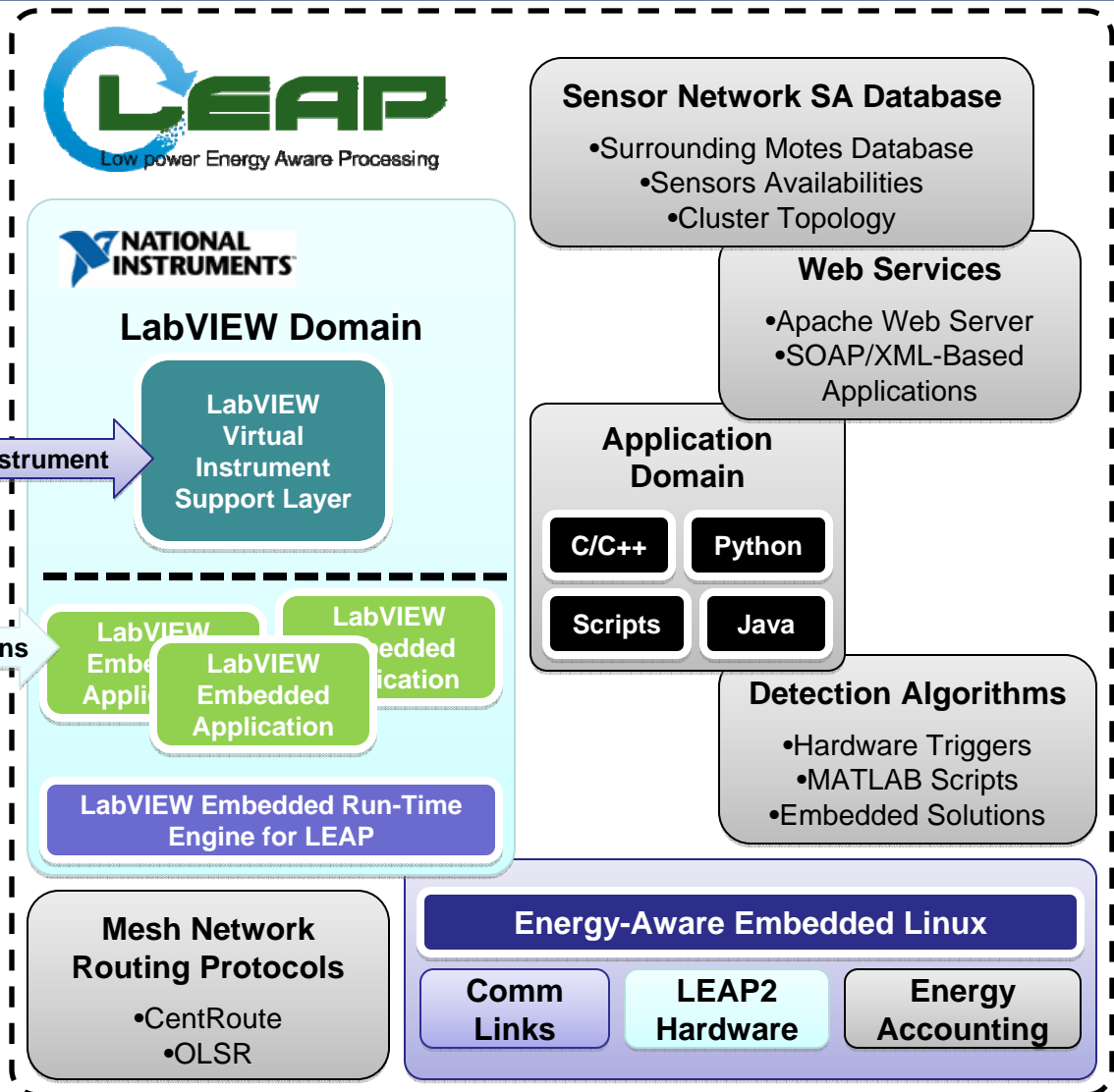


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LabVIEW for Energy Aware Systems



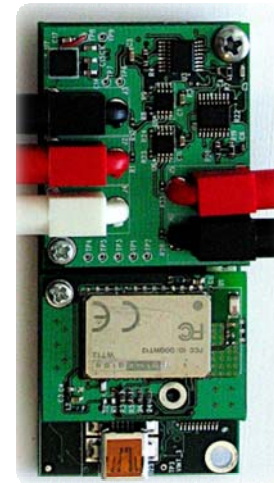
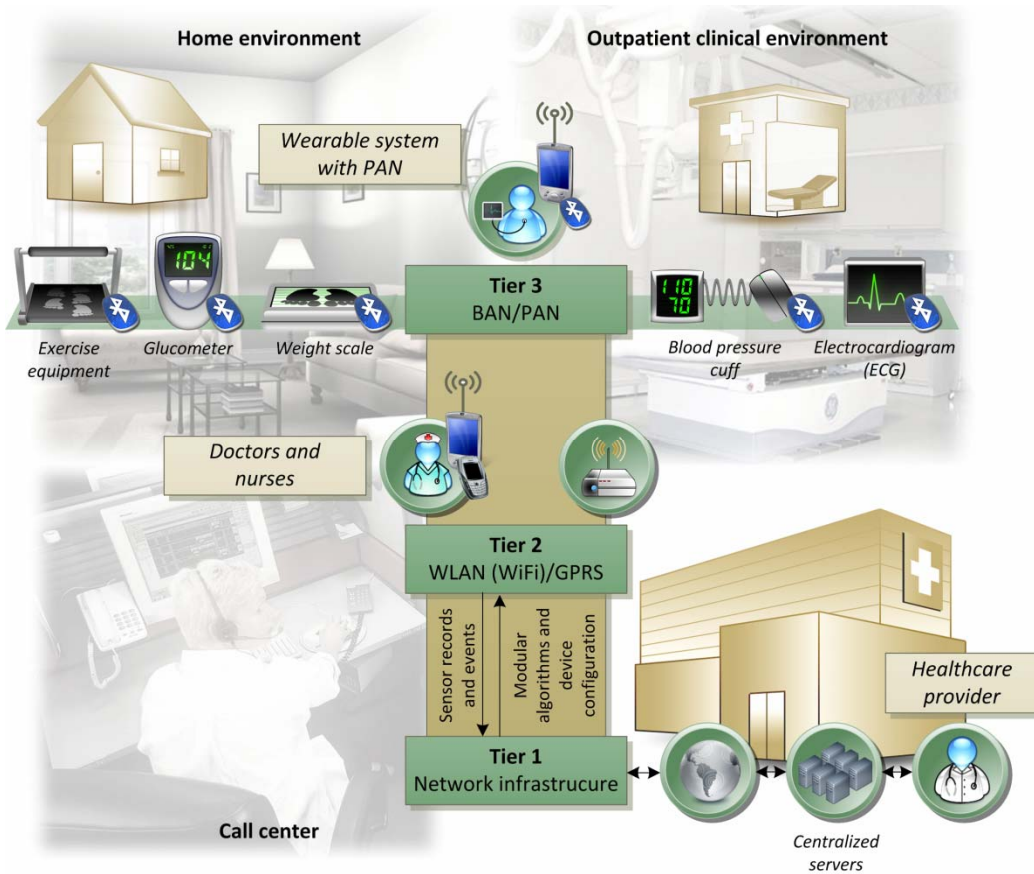
•Timothy Chow





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UCLA Telehealth: Driver for greener systems



μLEAP
 energy-aware
 Telehealth
 Platform

- Lawrence Au



Smart Cane
 Training and guidance
 in fall *prevention*