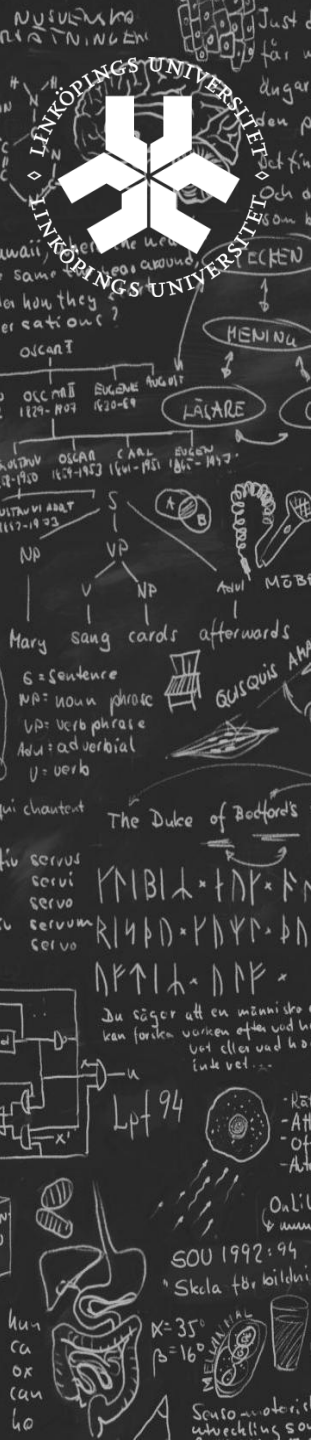

Somniloquoy: Augmenting Network Interfaces to Reduce PC Energy Usage

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LiU expanding reality

Motivation

- A number of idle computers remain switched on
  - 67% of office PCs are on outside working hours
  - Home PCs are on 34% of the time and used only half of it
- Reasons
  - Remote access
  - Quick availability
  - Support applications running in background

Problem

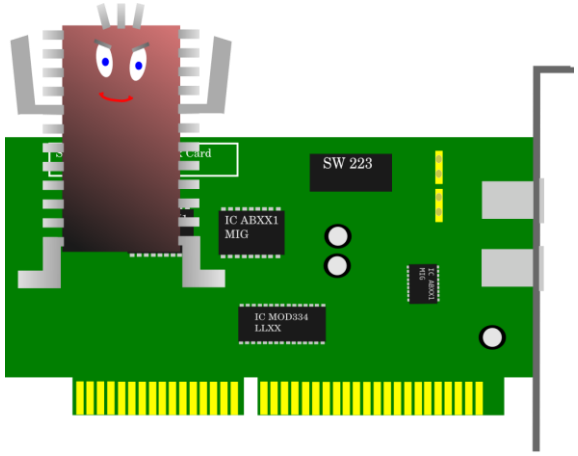
- Power saving mechanisms for computers exist
  - Sleep or suspend-to-RAM (ACPI state S3)
  - Hibernate (ACPI state S4)
- But they are not used because
  - Incompatible with remote network events
  - Network applications cannot keep presence

Somniloquoy

- Architecture to reduce energy consumption
  - Keeps PC available while it is in low power mode (ACPI S3)
  - Minimum level of activity is possible
- No changes in user experience
- No modification of network infrastructure neither servers

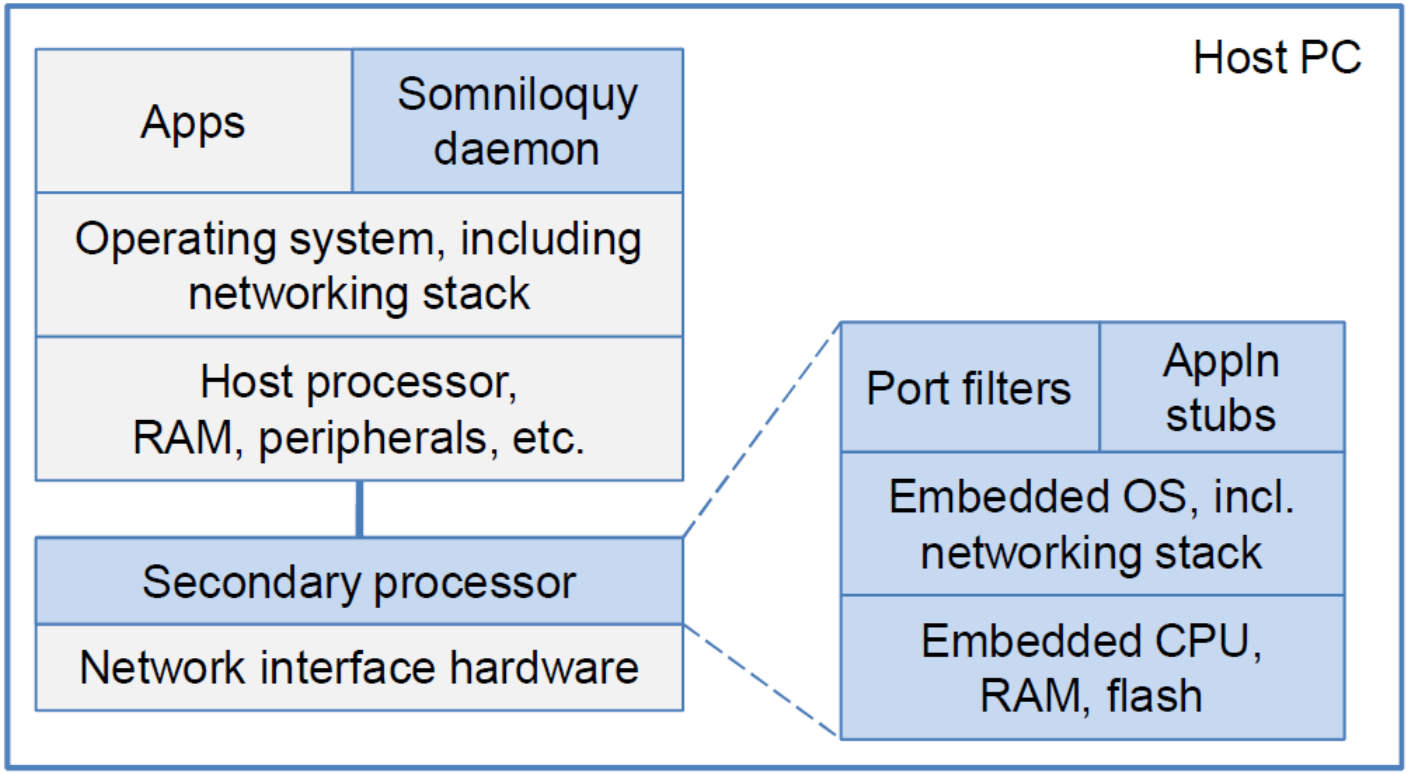
System achitecture

- Augmented PC network interface hardware



- Always on interface with low power embedded CPU
  - Includes small amount of memory and flash storage
  - Runs embedded operating system with TCP/IP stack

System achitecture



Operation flow

- PC is active and wants to go to sleep

1. Somniloquoy daemon captures sleep event
2. Network state is transfered to secondary processor
   (ARP table entries, IP address, DHCP lease, SSID…)
3. Configuration is transfered to secondary processor
   (events to wake up PC, application specific data…)
4. PC goes to sleep and secondary processor enabled

Operation flow

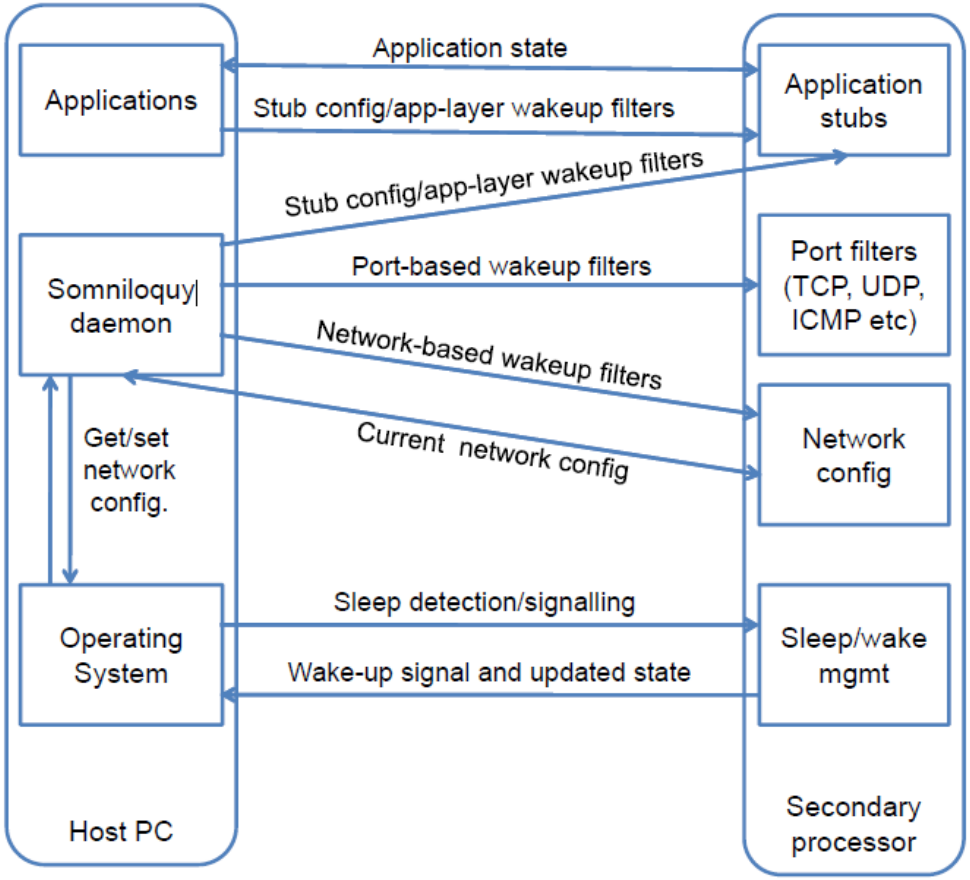
- PC is sleeping and event arrives

  1. Secondary processor is impersonating PC
  2. Incoming connection arrives and it is handled by secondary processor
  3. PC is waken up if required
  4. Network state and configuration is sent back to PC

PC wake up

- A process monitors the incoming network events
- Network events at different levels can trigger wake up
  - Packet level
    - Filtering techniques at various levels of network stack
      - Reception of a specific type of packet
      - Patterns of the content payload of packets
  - Application level
    - Specific code (stub) for each application supported
      - Reception of specific application event
      - Partial functionality implemented at secondary processor

Software components



Application stubs

- Keep partial functionality in the secondary processor
  - Without requiring PC wake up all the time
  - Presence, file downloading…
- Specific pieces of code for each application supported
  - Code runs in secondary processor
- Main PC is only switched on when really needed
  - To attend an incoming call or chat conversation
  - To copy a downloaded file to the hard drive

Developing an application stub

- Important decisions
  - Subset of application's functionality required
  - When to wake up the host processor
- Components
  - Main code at the secondary processor
  - Two callback functions at the host PC (sleep/wake up)
    - One transmits the application state when PC goes to sleep
    - Other checks the event that caused the wake up

Calculation of energy savings

$$\frac{E_{somniloquy}}{E_{host}}$$

$$E_{somniloquy} = E_{PCinSleepMode} + E_{PCinAwakeMode} + E_{SecondaryProcessor} =$$

$$= T_{sleep} \times P_s + (T_{awake} + d) \times P_a + (T_{awake} + d + T_{sleep}) \times P_e$$

P_s : Energy consumption in sleep mode

P_a : Energy consumption in active mode

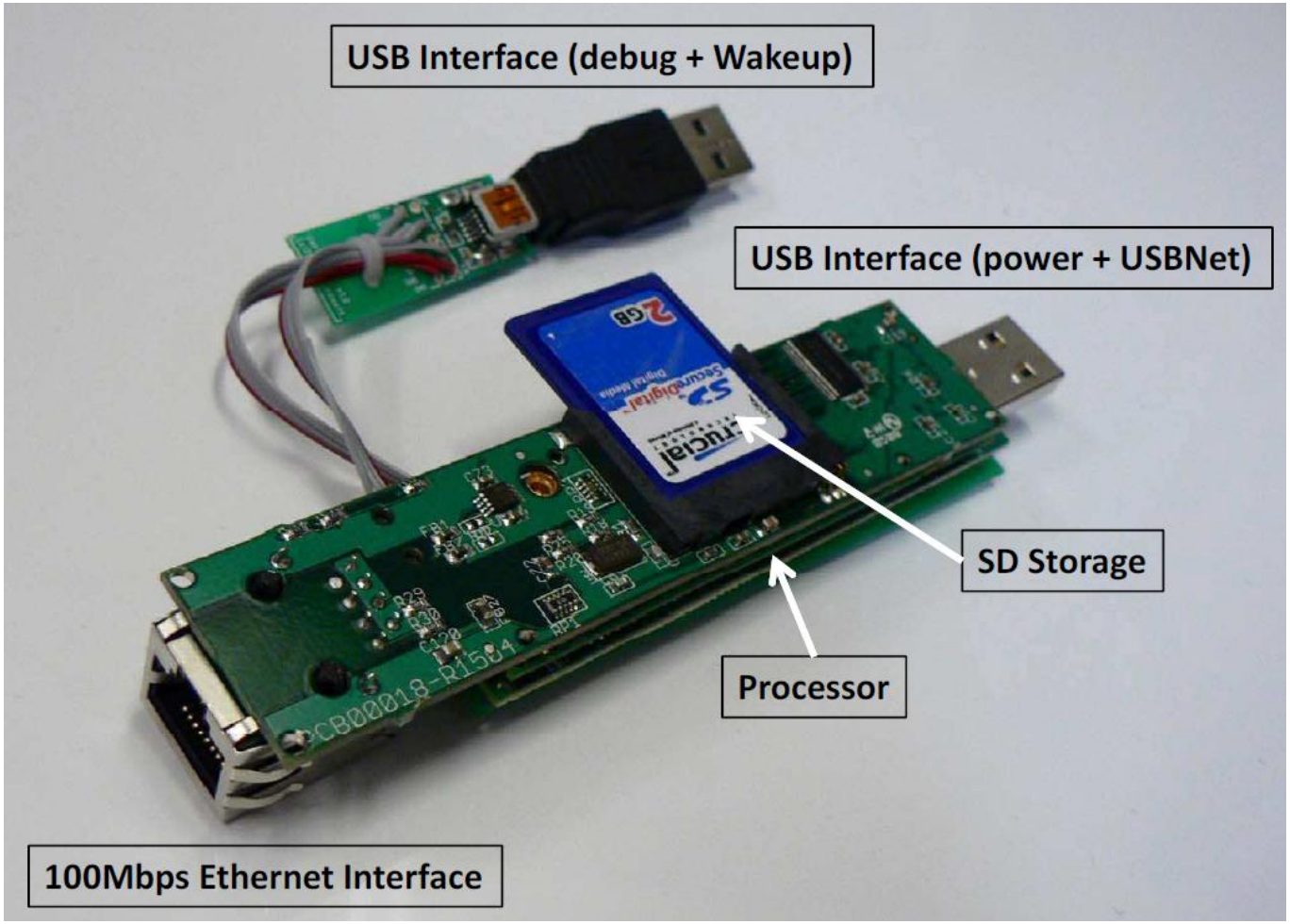
P_e : Energy consumption of secondary processor

T_{sleep} : Time PC is in sleep mode

T_{awake} : Time PC is in active mode

d : Transition time between modes

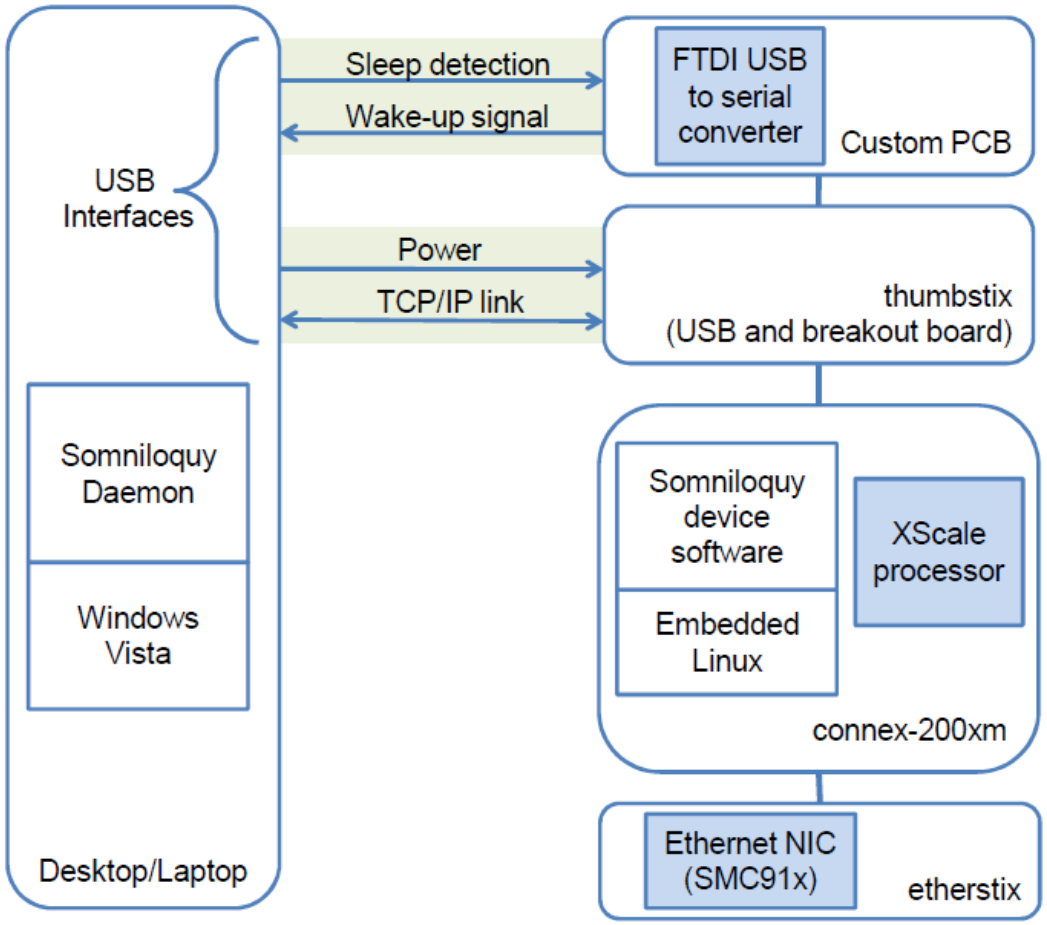
Prototype implementation



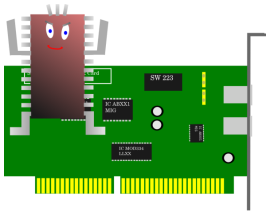
Hardware

- Gumstix platform
  - Low power modular embedded processor (200 Mhz)
  - 16MB non volatile flash and 64MB RAM
- Additional components
  - Etherstix 10/100BaseT Ethernet interface + SDCard slot
  - Wifistix NIC (Wi-Fi)
  - Thumbstix USB connector, serial connections and general purpose input and output connections (GPIO)
  - 2GB SD card
  - Extra USB to detect state of PC, wake it up and for debugging purposes

Block diagram of prototype



Three prototype variants



- Wired-1NIC
  - The prototype Ethernet replaces the NIC of the PC
    - It performs packet bridging
  - Restricted to 5Mbps due to bandwidth supported by the USBNet driver
- Wired-2NIC
  - While PC is active the NIC of the PC is used
  - While PC is sleeping the NIC of the prototype is used
- Wireless-2NIC
  - Same than before, but with 802.11 b/g interface

Applications supported without stubs

- Applications
  - Remote desktop (RDP)
  - Remote secure shell (SSH)
  - File access requests (SMB)
  - Voice over IP (SIP/VoIP)
- Port-based filter triggers when to wake up
- Request is attended when PC is on because of retrying

Applications supported with stubs

- HTTP downloads
  - Stub for *wget* application
  - Status is transferred from PC when it switches to sleep
    - URL, offset of download, buffer space available and credentials
- BitTorrent
  - Stub based on customised console-based client *ctorrent*
  - Status transferred from PC to secondary processor
    - Torrent file description and downloaded portion of the file
  - PC is waken up when file is finally downloaded

Applications supported with stubs

- Instant messaging
  - Stub based on console multi instant messaging client *finch*
  - Authentication credentials transfered when PC goes to sleep
  - PC is waken up when incoming message arrives

Evaluation

- System tested with different computers
  - Desktops: Dell Optiplex 745 and Dell Dimension 4600
  - Laptops: Lenovo X60, Toshiba M400 and Lenovo T60

- Methodology
  - Measurement of energy consumption of each platform
  - Calculation of energy savings and latency
  - Analysis of applications' performance
  - Quantification of Somniloquoy's energy savings

Evaluation setup

	Optiplex 745	Dimension 4600	Lenovo X60	Toshiba M400	Lenovo T60
Type	Desktop	Desktop	Laptop	Laptop	Laptop
CPU	2.4 Ghz Core2Duo	2.4 Ghz P4	-	-	-
RAM	2 GB	512 MB	2 GB	1 GB	1 GB
OS	Windows Vista	Windows XP	Windows Vista	Windows XP	Windows Vista

Energy consumption and latency of PCs

Condition	Optiplex 745	Dimension 4600	Lenovo X60	Toshiba M400	Lenovo T60
Idle state *	93.1 W	72.7 W	11 W	18.3 W	21.3 W
Suspend state (S3)	1.2 W	3.6 W	0.74 W	1.15 W	0.55 W
Time to enter S3	9.4 s	5.8 s	8.7 s	5.5 s	4.9 s
Time to resume from S3	4.4 s	6.2 s	3.0 s	3.6 s	4.8 s

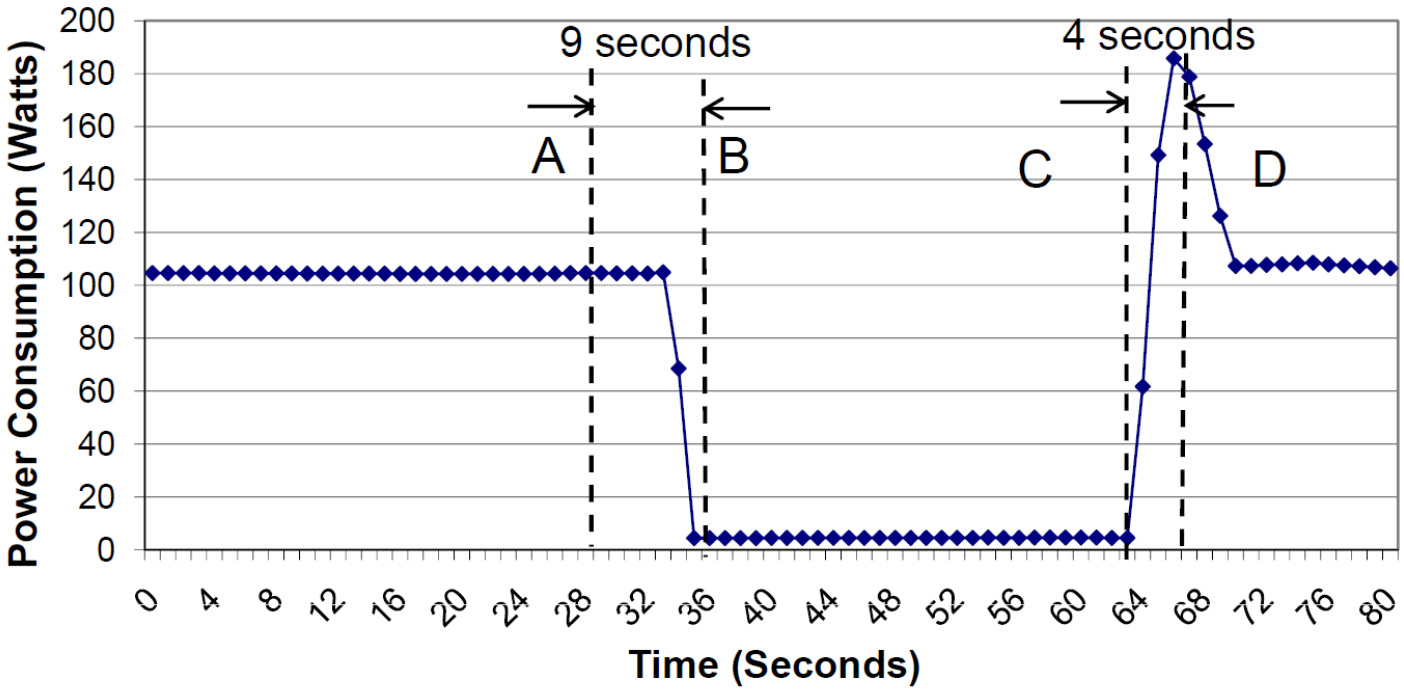
* Idle state with maximum optimisation (max number of components disconnected)

Energy consumption of gumstix platform

	Gumstix state	Power
	Wired version	
1	gumstix only - no Ethernet	210 mW
2	gumstix + Ethernet idle	1073 mW
3	gumstix + Ethernet bridging	1131 mW
4	gumstix + Ethernet + write to flash	1675 mW
5	gumstix + Ethernet broadcast storm	1695 mW
6	gumstix + Ethernet unicast storm	1162 mW
	Wireless version	
7	gumstix only – no Wi-Fi	210 mW
8	gumstix + Wi-Fi associated (PSM)	290 mW
9	gumstix + Wi-Fi associated (CAM)	1300 mW
10	gumstix + Wi-Fi broadcast storm	1350 mW
11	gumstix + Wi-Fi unicast storm	1600 mW

Operation of Somniloquoy

Consumption is reduced 24x in a Desktop



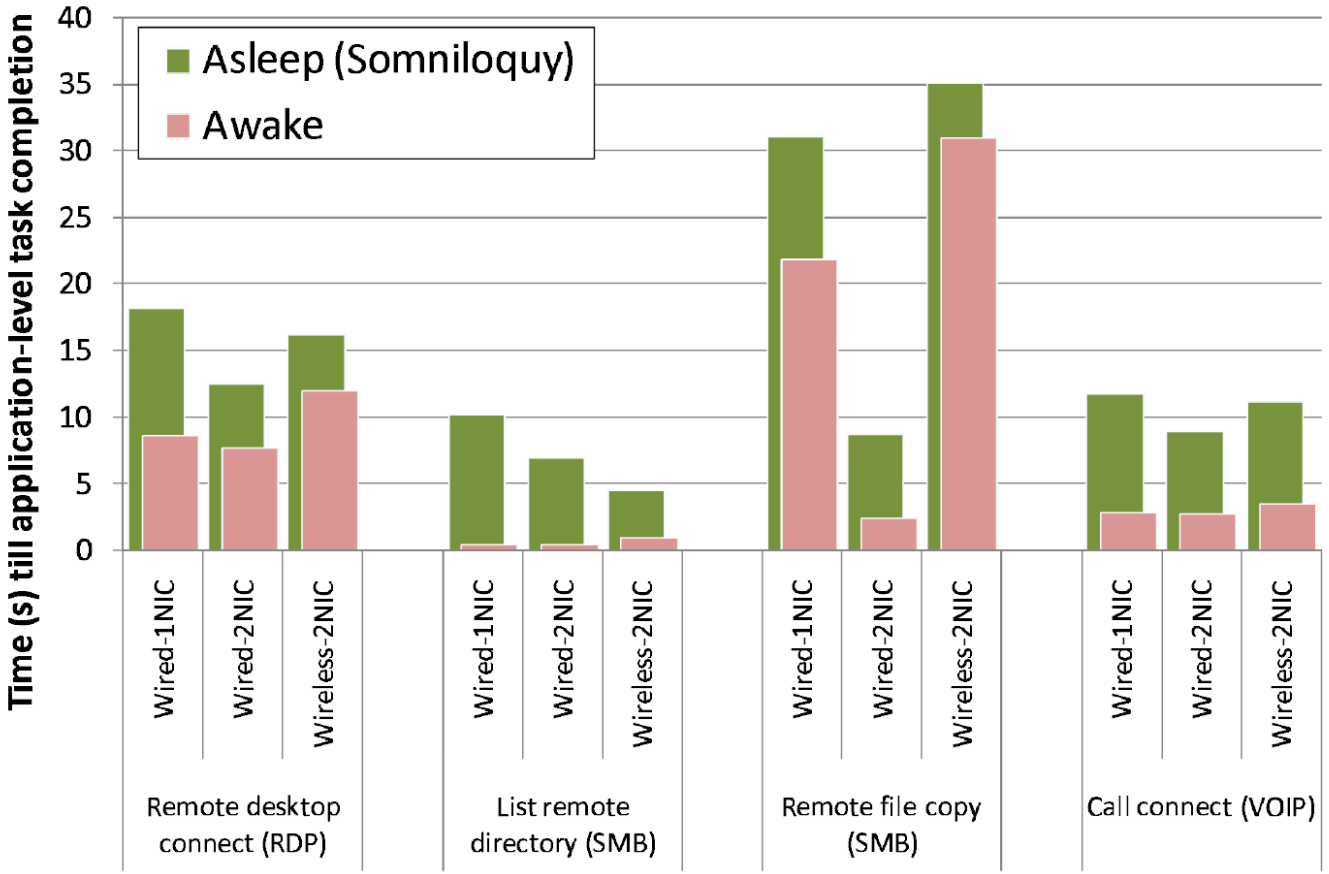
A-B Transition to S3

C-D Transition from S3

Application without stubs evaluated

- Remote desktop (RDP)
  - Process to initiate a remote desktop until it is displayed
- List remote directory (SMB)
  - Process to request a directory listing util it is received
- Remote file copy (SMB)
  - Process to transfer a 17 MB file
- Call connect (VoIP)
  - Process to establish a VoIP call

Latency of application without stubs



Performance of application with stubs

- Instant messaging
  - Keep presence of one or more IM accounts
- BitTorrent
  - Different cache size
  - One and two simultaneous downloads
- HTTP downloads
  - Download of a 300 MB file from local web server
  - One and two simultaneous downloads

Performance of application with stubs

Accounts	Processor 95th percentile	Memory 95th percentile
None	0.0%	5.9 MB
MSN only	10.0%	6.5 MB
MSN+AOL	21.6%	6.7 MB
MSN+AOL+ICQ	26.0%	6.9 MB

Instant messaging resources

Configuration	Processor 95th percentile	Memory 95th percentile
Single download		
4MB cache	16.0%	6.5 MB
8MB cache	16.0%	10.6 MB
16MB cache	16.1%	18.9 MB
Two simultaneous downloads (4 MB cache)		
1st download	16%	6.5 MB
2nd download	24%	7.0 MB

BitTorrent resources

Configuration	Processor 95th percentile	Memory 95th percentile
Single download		
2Mbps	9.2%	1.8 MB
4Mbps	21%	1.8 MB
8Mbps	50%	1.8 MB
Two simultaneous downloads (4 Mbps each)		
1st download	31%	1.8 MB
2nd download	26.3%	1.8 MB

HTTP download resources

Gumstix RAM: 64 MB

Energy savings

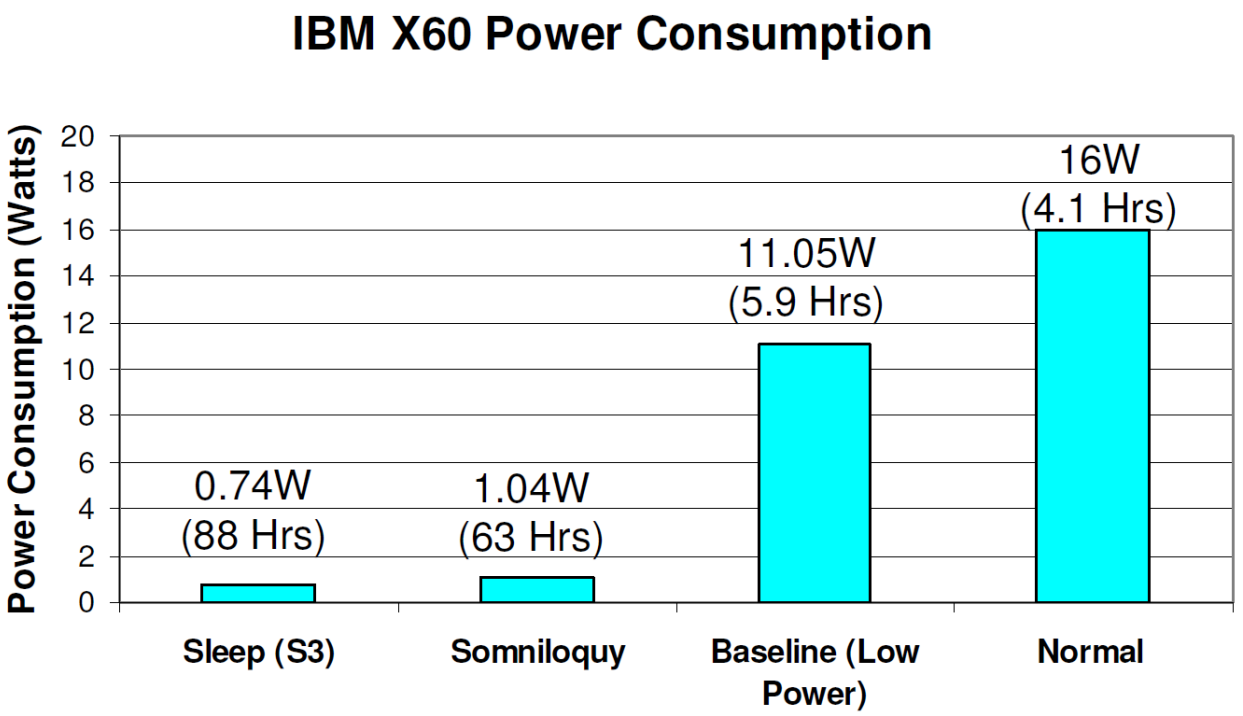
- Somniloquy can save 97 W in a desktop PC
  - Normal operation consumes 102 W
  - Sleep mode and Somniloquoy enabled consumes < 5 W
- In a computer used 27% of time
  - 620 kWh of savings / year
  - 378 kg of CO_2 / year
  - 56 US$ / year

Energy savings in desktop PCs

Category	Savings
Idle < 25% of the time	38%
Idle between 25% - 75% of the time	68%
Idle > 75% of the time	85%

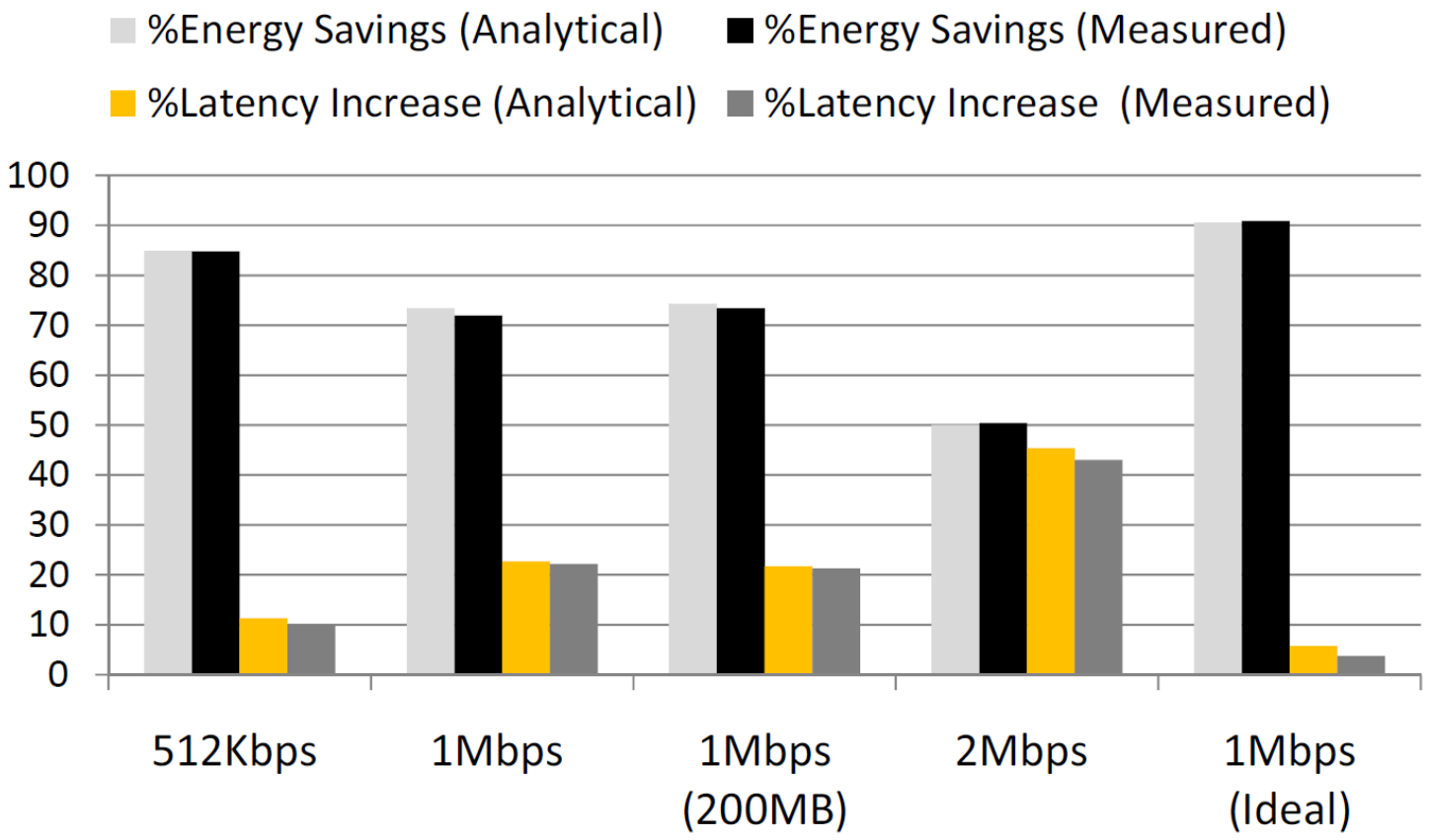
Results obtained with usage data of 22 PCs

Energy savings in laptops



In parenthesis maximum number of battery hours in different states

Energy savings for web downloading



File size: 300 MB

Flash storage: 100 – 200 MB

Conclusions

- An architecture to reduce energy consumption is presented, implemented and evaluated
- The prototype is suitable for any standard PC
- High benefits for always-on PCs to keep network presence or low complexity network tasks are shown