

Energy Efficient Mobile Systems

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Motivation

Design policies for energy-efficient mobile systems

- ❑ Create a reference database of power consumption and performance characteristics of Symbol® PPT 2800 and Spectrum24™ WLAN card
- ❑ Secure wireless data transactions
 - Benchmark software implementations of DES, 3DES and AES encryption
 - Study the S/W vs. H/W tradeoffs for encryption
- ❑ Wireless data transmission
 - Study the effects of RF signal power on the WLAN card power

Mobile Test Bed

Spectrum 24 11 Mbps network adapter card

Tektronix TDS 3054 Oscilloscope

Sycard PCI 100 extender card

Symbol PPT 2800



Tektronix TCP 202
current probe

To the Li-ion 4 V battery

□ Develop a mobile test bed for accurate and efficient energy measurements

- Tektronix TDS 3054 oscilloscope: 4 channel, 500 MHz, 5 GS/s
- Tektronix TCP 202 current probe: DC to 50 MHz, 15A DC + Peak AC, 500×10^{-6} Amp * Sec product, Min sensitivity: 10 mA/div, DC accuracy: $\pm 1\%$ with probe calibrator, $\pm 3\%$ without probe calibrator

Profiling Spectrum24 LA-4121 WLAN card

	CAM		P1		P2		P3		P4		P5	
	I (mA)	P (W)	I (mA)	P (W)	I (mA)	P (W)	I (mA)	P (W)	I (mA)	P (W)	I (mA)	P (W)
Sleep	-	-	20	0.1	20	0.1	20	0.1	20	0.1	20	0.1
Idle	170	0.85	31.5	0.16	31	0.16	30	0.15	30	0.15	29.5	0.15
Rx	190	0.95	190	0.95	190	0.95	190	0.95	190	0.95	190	0.95
Tx	410	2.05	410	2.05	410	2.05	410	2.05	410	2.05	410	2.05
Rx timeout¹ (mS)	-		200		200		50		50		25	
Tx timeout² (mS)	-		500		300		100		25		25	
Response time(mS)	-		150		180		300		300		300	

- ❑ LA-4121 supports five polling modes (P1-P5) and a CAM mode
- ❑ Dynamically matching the mode of operation of the WLAN card to the application characteristics is desirable for energy efficiency

¹ Stays in the CAM for this time after receiving a frame.

² Stays in the CAM for this time after transmitting a frame.

Profiling DES, 3DES and AES on 2800

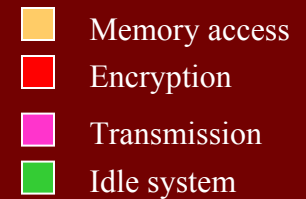
- ❑ Optimized for throughput, entire code (instruction+data) running from cache
- ❑ 16 KB instruction cache, 8 KB write back data cache (32-way set associative)

Encryption²	DES	3DES	AES
Time/bit (μS)	0.07	0.20	0.04
Avg. Current (mA) @ 4 V	202.05	166.29	189.62
Energy/bit (μJ)	0.06	0.13	0.03
Bit rate (Mbps)	14.16	4.98	25.96
Instruction/Data (Bytes)¹	3144/2592	8660/2592	4824/4112
Key Schedule	DES	3DES	AES
Time (mS)	0.23	0.71	0.0075
Avg. Current (mA) @ 4 V	192.15	190.24	174.48
Energy (μJ)	176.78	541.79	5.22
Instruction/Data (Bytes)	468/0	584/0	1680/1028

¹ Corresponds to only either encryption or decryption

² DES, 3DES: Encryption (ECB mode), 64 bit data block, 64 bit key, AES: Encryption (ECB mode), 128 bit data block, 128 bit key

Software vs. Hardware Encryption



Encryption in hardware

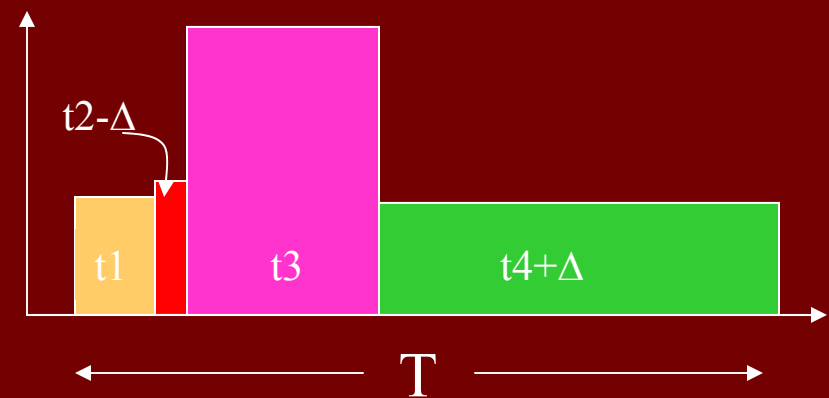
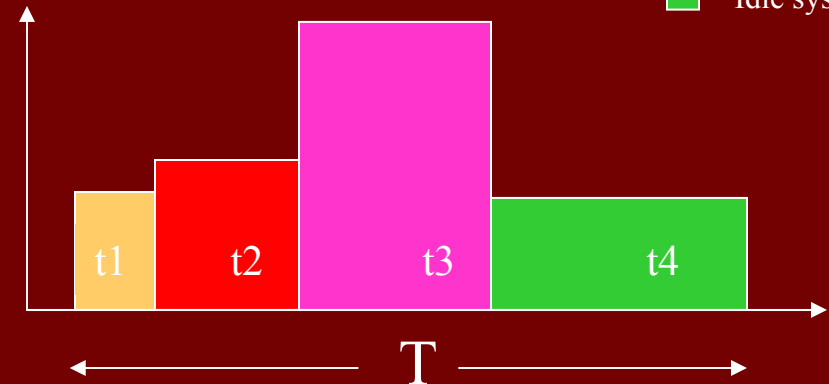
Pros

- Faster
- Less power
- More secure (e.g. against physical and intercepting attacks)

Cons

- Cost
- More area

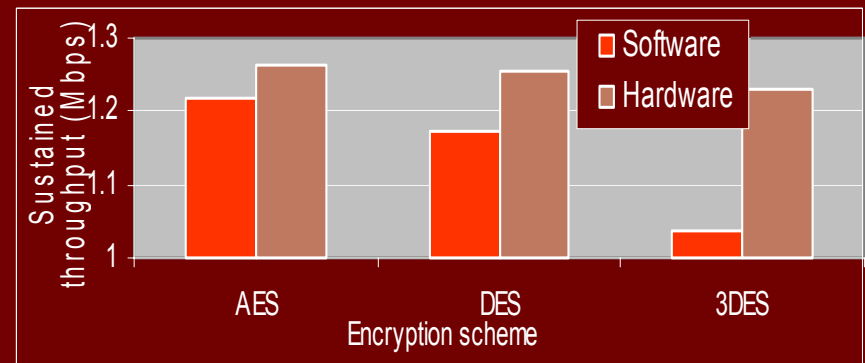
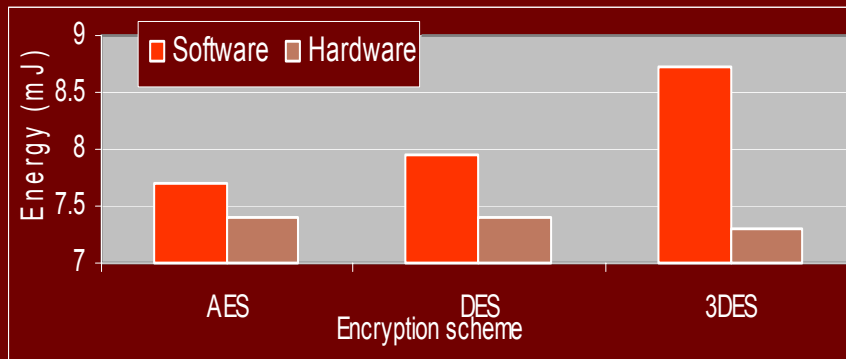
Energy efficient??



S/W vs. H/W Encryption Energy

Encrypting and transmitting (P1 mode) 1000 UDP packets of size 600 bytes

	Application	Tasks						
	3DES + Tx	3DES (S/W)	Tx	loop + mem acc.	Idle system ⁴	Total (S/W)	3DES (H/W)	Total (H/W)
Time/P (ms)	4.628	0.965	1.14 ¹	0.04	2.483	4.628	0.241	3.904
Av. Current/P (ma)	460.56	375 ³	800 ²	375 ³	360			
Av. Power/P (w)	1.84225	1.5	3.2	1.5	1.44		0.05	
Energy/P (mj)	8.526	1.448	3.648	0.06	3.576	8.732	0.012	7.296



¹ Though the actual Tx time for 600 bytes packet is between 0.74 to 0.8 ms, system response is sluggish by 0.25 to 0.35 ms.

² System current consumption during active transmission, ³ DES + System + WLAN card in CAM mode

⁴ Idle system time deduced as Col 1 – (Col 2 + Col 3 + Col 4)

WLAN card throughput profiling

UDP packets, 1400 bytes/packet, open system, CAM mode, AP firmware V 2.51

	Throughput (Mbps)		
	Spectrum24-4121 Driver V 2.2 / 3.0	Cisco-350 Driver V 6.64.0.0	Lucent-ORiNOCO Driver V 7.06
Symbol PPT 2800	2.73 / 1.8512	-	2.76
Compaq Ipaq	4.38 / 2.686	4.6	4.752

Two bottlenecks

Hardware

▪ Integrated display controller

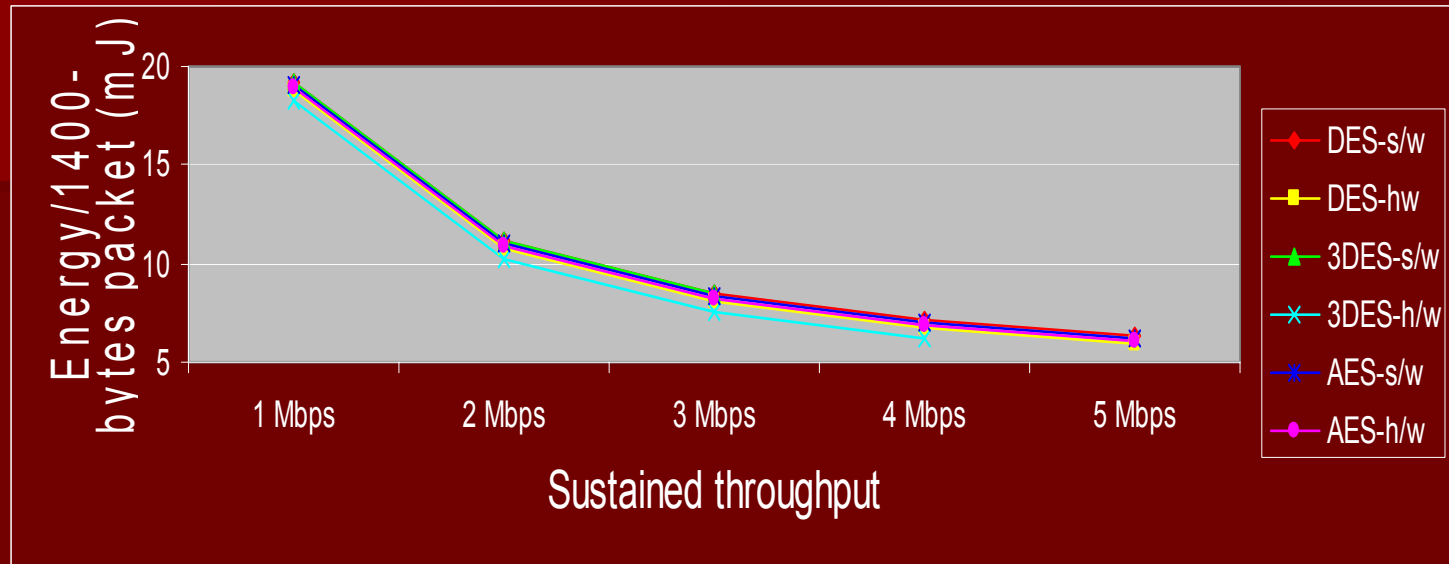


▪ PCMCIA interface driver



WLAN card driver

Secure Session Energy vs. Throughput



❑ For a secure session over WLAN, energy saved by implementing encryption in h/w is not significant (16.44% for 3DES and for 3.77% for AES). This is because energy consumed by encryption is small as compared to the energy consumed by transmission and by idle system

❑ Reception power, sleep power and transmission power, in that order, affect the system energy consumption characteristics over a long term of use

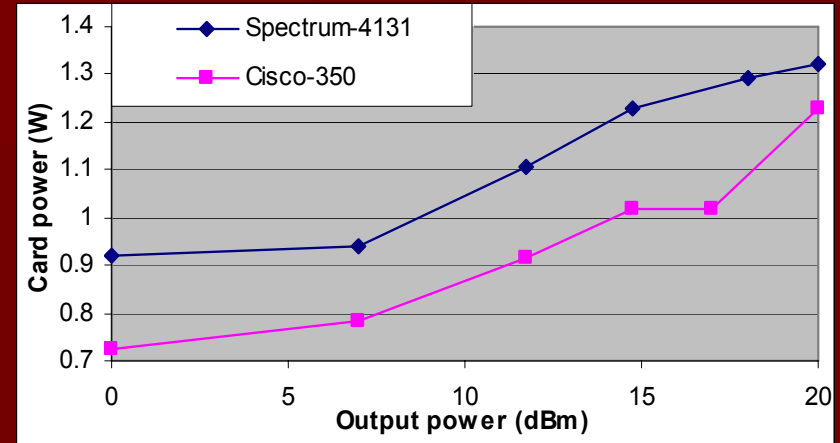
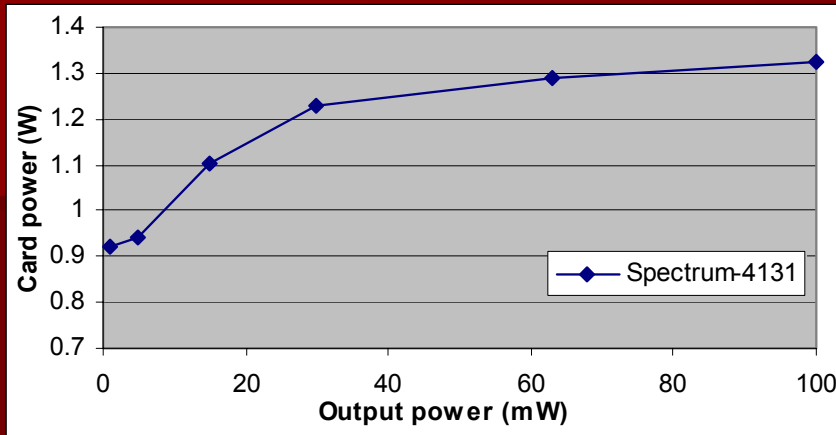
RF Signal Power vs. WLAN card power

Trilogy access point firmware v 2.51		Tx					
		Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Spectrum24 –4131 Driver V 3.0.18.11	O/P power (mW)	100	30	15	5	1	-
	WLAN current (mA)	401	373	335	285	279	
Cisco – 350 Driver V 6.64.0.0	O/P power (mW)	100	50	30	20	5	1
	WLAN current (mA)	373	308	308	278	238	220

PRISM 2.5 current consumption (mA)					
	Integrated MAC controller + BBP	I/Q Mod /Demod	RF/IF Converter	Power Amplifier ¹	TOTAL
Component	ISL 3874	HFA3783	ISL 3685	ISL 3984	
Rx	170	36-40	32-38 (HG-LNA) 25-32 (LG-LNA)	-	238-248 231-242
Tx	170	32-40	41-45	137 @ 18 dBm	380-392

¹ According to Trilogy3 documentation (rev. 06/29/2001) it uses MAX24PA (MAX2240) PA (consuming 107 mA @ 20 dBm) instead of ISL 3984

Choice of RF signal power



❑ Power consumed by WLAN card varies significantly as a function of RF signal power

❑ WLAN card consumes roughly the same power corresponding to 5 mW-1 mW and 100 mW-63mW RF power range. Assuming a single AP cell, operating at the high end ensures less packet error rate and thereby less WLAN card energy consumption. Further study is required for multi-cell environment

❑ Designing policies for dynamic RF signal power configuration based on WLAN card power characteristics, distance from the access point and network conditions

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