L-IOT : A FLEXIBLE PLATFORM FOR ULTRA LOW POWER IOT

Ivan MIRO-PANADES, Edith BEIGNE | Workshop NVRAM | May 2017
• Motivation
• L-IOT architecture
• Case study: Wake-Up Radio
• LIOT available offer
• Conclusions
• **Many different applications:**
  - ... with variable Energy needs

• **Changing environments impacting:**
  - Energy harvesting
  - Communication channels
  - Sensing
  - Image
  - Security level
USUAL SMART DEVICE ARCHITECTURE AND APPLICATIONS

Applications

- Video surveillance Smart Camera
- Secure wireless communications
- Data Fusion
- Tracking and Monitoring

Energy needs

Perf./

pW-µW area

Micro Mote M³
15nW stdby
304nW (motion detection)
180nm
Kim, G. et al, VLSI’14

SleepWalker
1.7µW stdby
7µW/MHz@0.4V(25MHz)
65nm
Bol, D. et al, JSSC’13

ARM M0+ SubSyst
80nW stop
2mW@0.85V(30MHz)
65nm
Myers, J. et al, ISSCC’15

ST STM32L0
0.27µA stdby
139 uA/MHz(32 MHz)
130nm
STM, STM32L053C8,’14

TI CC2650
1µA stdby
6mA (RX/TX mode)
TI, CC2650,’15

mW area

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USUAL SMART DEVICE ARCHITECTURE AND APPLICATIONS

Applications

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Perf./Energy needs

A flexible System is required to cover energy & applicative IoT needs

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L-IOT: A FLEXIBLE PLATFORM IN FDSOI28

- A flexible and **fully integrated** platform for a fragmented market
- FDSOI technology brings more flexibility
- Autonomous system
- Low power consumption and adaptive blocks

**Applications**
- Video surveillance
- Smart Camera
- Secure communications
- Data Fusion
- Tracking and Monitoring

**L-IOT Architecture**

<table>
<thead>
<tr>
<th>ALWAYS-RESPONSIVE SUB-SYSTEM</th>
<th>ON-DEMAND SUB-SYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>pW-μW area</td>
<td>mW area</td>
</tr>
</tbody>
</table>

**Perf./Energy needs**
Radio Sensing

Wake-Up Computing

Energy management
L-IOT: A FLEXIBLE PLATFORM

Adaptive Always-Responsive/On-Demand according to energy levels
• Case study: Wake-Up Radio
STATE OF THE ART OF RADIO RECEIVERS

UNCERTAIN IF TECHNIQUE

Classic Receiver

Uncertain IF receiver

LNA

Narrow Band amp.

High Q M.N.

Wide Band amp.

Free running VCO
NPATH FILTERING

Passive Mixer

RF<sub>in</sub>  \(\rightarrow\)  \(Z_{RF}\)  \(\rightarrow\)  LO  \(\rightarrow\)  \(Z_{BB}\)  \(\rightarrow\)  LPF  \(\rightarrow\)  IF

2<sup>nd</sup> order bandpass

1<sup>st</sup> order lowpass

\(Z_{RF}\)

\(Z_{BB}\)

R<sub>switch</sub>

f<sub>LO</sub>

freq

0

freq

20dB/dec
THE SLIDING LO TECHNIQUE

Wake-up Radio

Inputs

- $G_{AGC}$
- BW
- $f_{LO}$

RF Front-end

- LO
- IF
- LNA
- LPF
- VGA

Outputs

- Only « 0 »
- Only « 1 »
- Wake-up interruption

Digital Base Band

Context-aware, band of interest location stored into NVM

Band of interest

IF amplifier BW

Freq
• Uncertain IF N-path filter Receiver
  • 28 nm FDSOI technology
  • Sensitivity -80 dBm
  • 50 µW power consumption
  • Frequency bands : 433MHz -> 2.4G
  • No ext. matching
  • OOK modulation
  • Standards : Proprietary
THE PROPOSED ARCHITECTURE
THE WAKE-UP RADIO CIRCUIT

The Wake Up Receiver!
0.15 mm²
FIRST MEASUREMENT RESULTS

Application scenario

<table>
<thead>
<tr>
<th>Duty-Cycle</th>
<th>$P_{\text{AVERAGE}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 %</td>
<td>0.54 µW</td>
</tr>
<tr>
<td>1 %</td>
<td>1 µW</td>
</tr>
<tr>
<td>5 %</td>
<td>3 µW</td>
</tr>
</tbody>
</table>

Duty-cycle needed!
• LIOT available offer
L-IOT AVAILABLE OFFER

Wake-Up
- Wake-up Controller
- Wake-Up radio
- Energy controller
- ULP/ULL memory

Power Management
- Distributed Back Bias Generator
- LDO
- Frequency generation FLL
- Real Time Clock
- Voltage Hopping
- Asynchronous service Network

Security
- AES encryption
- PRESENT encryption
- Polymorphism algorithms

Computing
- Cortex M0+
- Adequate computing
- Coming Next

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LIOT AVAILABLE OFFER

Wake-Up

Asynchronous Wake-Up Controller for very fast wake-up (55ns@0.6V)
Computing capabilities at low voltage
With compiler and debugger

Wake-Up radio for less than 50µW
Covers all bands from 433MHz to 2.4GHz
Embedded LDO and oscillator (no PLL)
-60 dBm sensitivity for 48µW power consumption and
1µW when using 1% duty-cycling
Area 0.15mm²

Energy controller based on energy harvesters control for less than 1µW
Select the best source of energy in function of the circuit needs
Unused harvested energy is used to charge the battery

Self-timed SRAM memory
Suited for Wake-up Controller
Working down to 0.4V
Leakage of 1pA/bit at retention mode
L-IOT AVAILABLE OFFER

Power Management

- Distributed Back Bias Generator
- LDO
- Frequency generation FLL
- Real Time Clock
- Voltage Hopping
- Asynchronous service Network

Low area and low power Back Bias generator with automatic process and temperature circuit compensation

Ultra low power LDO for 0.95V delivery for 100µA current
Power OFF capability

Fast reprogramming Frequency Locked Loop delivering between 50MHz and 2GHz
Low area footprint 2100µm²

Real Time Clock without external component and low power 60nW @1V
Area footprint 0.01mm² including voltage regulation and clock trimming

Voltage selector between three voltages ex. 0.5V - 0.8V – 1V with power gating capability
Transition in less than 100ns transition with ~nW leakage power consumption
Area 0.045mm²

Dedicated service network for reconfiguration
Automatic flow control mechanism when crossing multiple power domains
Serial or parallel interface
L-IOT AVAILABLE OFFER

Security

- AES encryption
  - AES algorithm implemented in hardware
  - 128 bit key
  - Variable data length

- PRESENT encryption
  - PRESENT algorithm implemented in hardware
  - 128 bits key
  - Variable data length

- Polymorphism algorithms
  - Polymorphism algorithms for software security
L-IOT AVAILABLE OFFER

- **Cortex M0+**
  - Volatile (and Non volatile) Cortex M0+
  - 20MHz up to 250MHz @ 0.6V using Back Biasing

- **Adequate computing**
  - Adequate computing arithmetic units
  - Using Back Biasing up to 60% power gains

- **Coming Next**
  - Imagers
  - Neurocomputing
  - RISC V processor implementation
• A flexible platform suitable for a fragmented market
• Ultra low energy and adaptability are key technologies provided by L-IOT
• NVM will further reduce the power consumption thanks to instant-ON/OFF capabilities and context information
• Full integration and global optimization in FDSOI technology
ACKNOWLEDGEMENTS & REFERENCES

• **Contributors:**

• **Acknowledgments**
  - THINGS2DO project (JTI Contract Number 621221), co-funded by grants from France and the ECSEL Joint Undertaking.
  - BENEFIC project (CA505), co-funded by the framework of CATRENE, the EUREKA cluster for Application and Technology Research in Europe on NanoElectronics, and National Funding Agencies of France, the Netherlands and Portugal
  - ST Microelectronics

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