

# Low-power, Low-cost Software Defined Radio and Its Applications

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# OST/GPT Company Overview

## OST/GPT 概况



### Wuxi DSP Acquires Sandbridge Design Team/Licensed SB3500

#### 无锡DSP收购Sandbridge设计团队/许可SB3500

- Multithreaded DSP Core Microarchitecture and Chip Design  
多线程DSP核心微架构和芯片设计

### Optimum Semiconductor Technologies, Inc. (OST)

- The Wuxi DSP wholly owned US Company  
无锡DSP全资美国子公司

### General Processor Technologies (GPT)

- IP Licensing Company 知识产权 (IP) 许可公司
- A name owned by Optimum Semi OST持有的名称
- Processors, IP cores and accelerators 处理器, IP核和加速器
- World-wide 世界范围

### Value Proposition 价值定位

- Software reuse 软件重利用
- Easy integration in large SoC's 易于集成在大型系统芯片中
- Scalable low power multithreaded technology 可扩展的低功耗多线程技术
- Supporting mobile devices through basestations 通过基站支持移动设备



# The Multimode Design Problem

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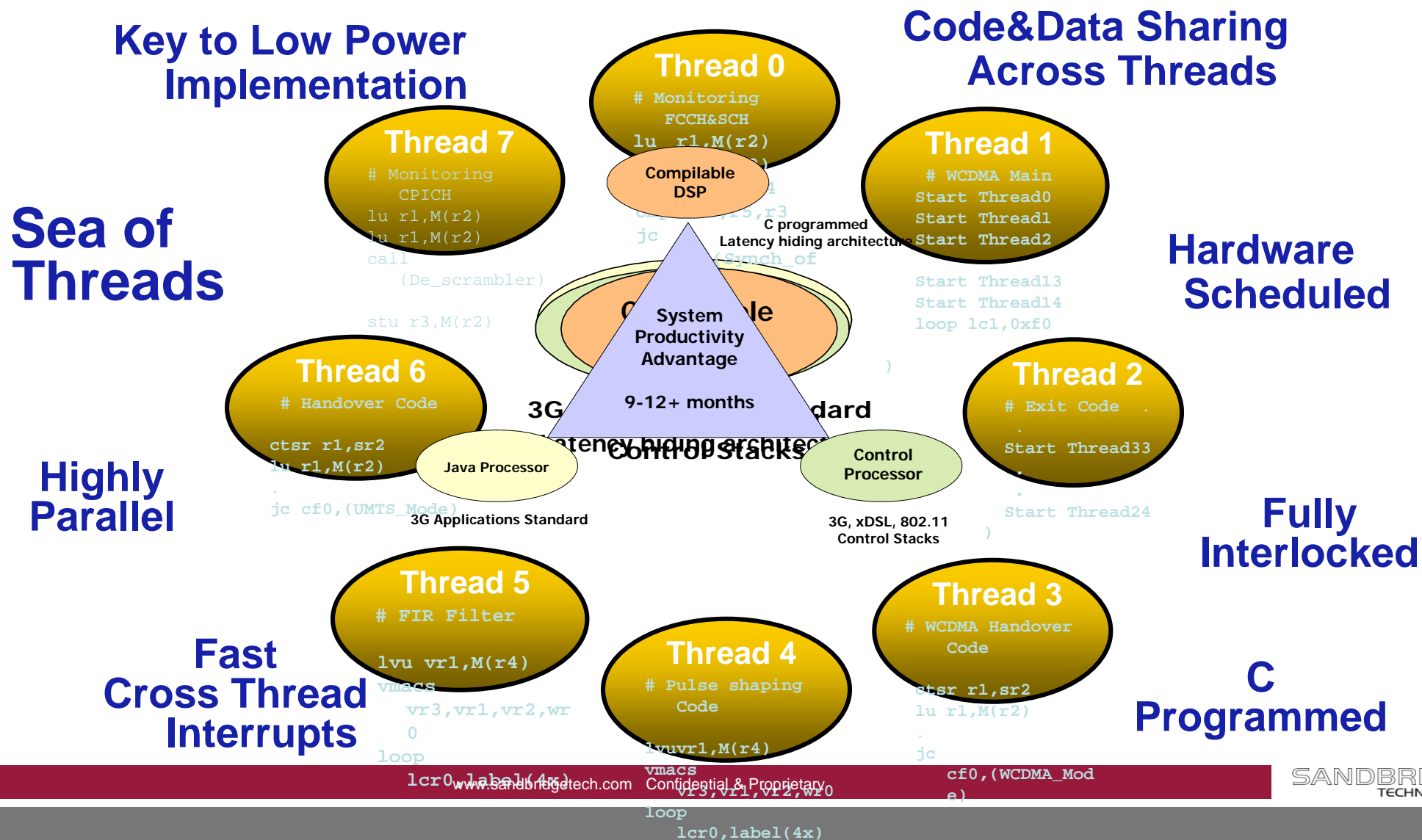
## Requirements

- ▣ Able to execute many systems
- ▣ Handset operation
- ▣ Able to handover between systems seamlessly
- ▣ Able to execute multiple systems simultaneously

## Design

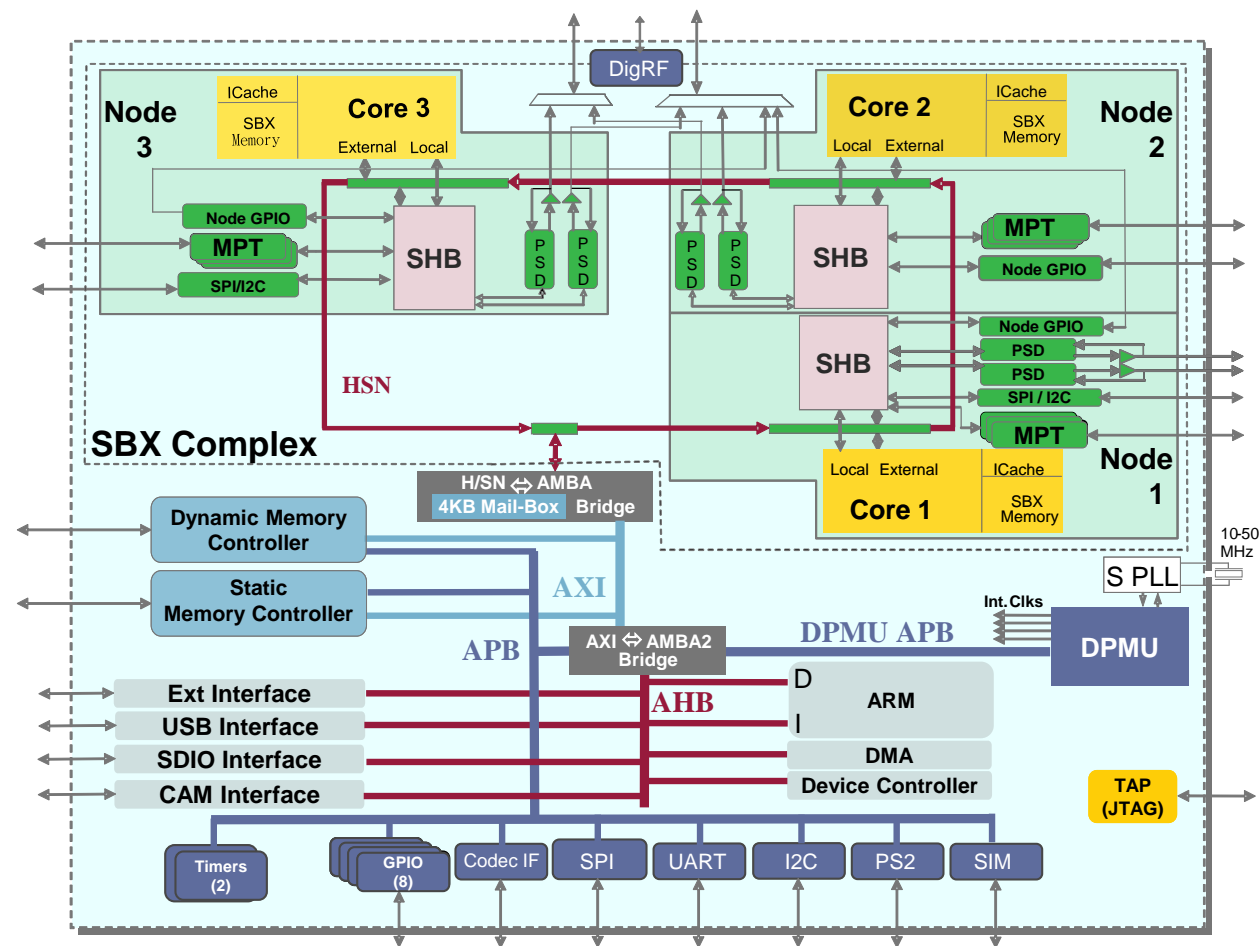
- ▣ A programmable solution
- ▣ Ultra low power
- ▣ Context switch in  $<1\mu\text{sec}$ 
  - A processor
- ▣ Arbitrarily interruptible
- ▣ A parallel processor
- ▣ A real-time processor

# Multithreaded Architecture Enables C



# SB3500 System-on-Chip

- ❑ SBX 2.0 Architecture
- ❑ Three 600MHz Cores
  - 4-way multithreaded
  - 16x16b SIMD per core
  - Comms: FFT, viterbi, turbo, pixels, GF, +/- 1 cor
  - Multimedia: pack/unpack, sum of diff, dct/idct
- ❑ 65nm LP
  - 75mW@1V
  - 0.25mW/MHz, 0.016mW/MMAC
  - ~30 sq mm
- ❑ 15-20Mbps wireless communications
  - 100% Software implementation
- ❑ Full range of IO's incl. DigRF 3.09



# Power Aware Implementation

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## Dynamic clock reconfiguration for all processing elements

- ⌘ De-coupled processing elements – independent frequency adjust per processor
- ⌘ Glitch-less frequency change – accomplished through writes to clock configurations registers

## Dynamic and coarse clock gating

- ⌘ Dynamic clock gating - accomplished via HW decode of executing instruction
- ⌘ Coarse clock gating – accomplished via writes to control registers

## Customized flops

- ⌘ Reduction of clock-tree loads

## Bus/net toggle reduction

- ⌘ Controllers with “One-hot” decoders and multiplexers
- ⌘ Instruction-based output gating

## Memories at half-frequency of Unit frequency (banked)

- ⌘ Lower clock power & system net toggle

# Compiler Optimizations – Dragon Book +

## DSP Optimizations

Saturation Arithmetic  
Fixed Point Semantic  
Analysis  
Bit-exact ETSI compliance

## Vector Optimizations

Vector Loads  
Vector Stores  
Vector Arithmetic  
Vector Reduction  
Saturating Vector Operations

## Multithreaded Optimizations

OpenMP  
Automatic Parallelization  
Automatic Multithreading

## Loop Optimizations

Loop Invariant Code Motion  
Strength Reduction  
Induction Variable  
Elimination  
Loop Splitting  
Software Pipelining

## Interprocedural

Constant Propagation  
Memory Disambiguation  
Function Inlining  
Alias Analysis

# Sandbridge Software PHY Implementations

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## Cellular

- ⌘ HSPA/EDGE/GPRS/GSM
- ⌘ Rev B/A / 1xEVDO / IS-95
- ⌘ LTE

## Broadband

- ⌘ WiMax – 16d/e
- ⌘ WiFi – 11a/b/g/n

## Location-based

- ⌘ GPS
- ⌘ Galileo

## Broadcast

- ⌘ DVB-H

## Multimedia

- ⌘ FM radio
- ⌘ MP3
- ⌘ MPEG-4
- ⌘ H.264

## Other

- ⌘ S-Video

**VALIDATED from RF -> PHY**



# System Designs with RF

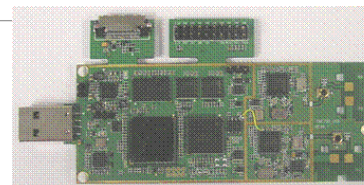
WCDMA



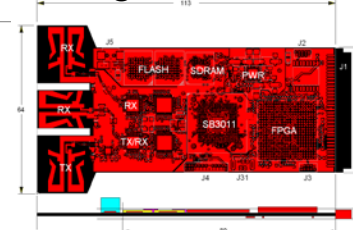
MIMO DVB-T



USB WiBRO



16b/g/n PCMCIA



GSM/GPRS



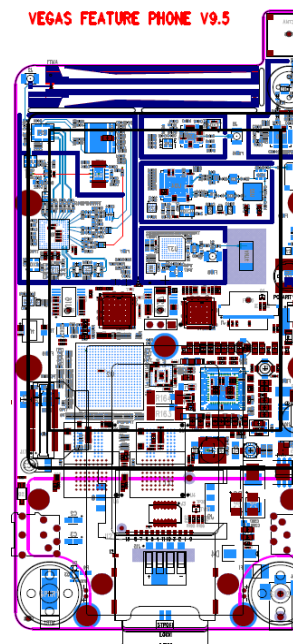
GPS



WCDMA



PDA Smartphone



CDMA-2k



Analog/Multimode TV



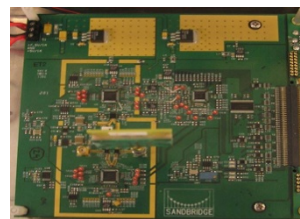
1xEVDO



802.11b



WiMax / 802.11a,g



TD-SCDMA  
(not shown)

# Awards

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## World Economic Forum

- Technology with capability to change the world

## 2009 EE Times ACE Finalist Most Innovative Mobile Processors

- Intel 45nm Atom Processor
- Qualcomm QSD8650 Mobile Processor (Snapdragon Platform)
- Samsung S5L8900B01 Applications Processor
- Sandbridge SB3500 Flexible Baseband Processor
- Texas Instruments 65nm OMAP3530 Applications Processor

## MWC First LTE handset modem

- Partnered with Samsung. Connected to commercial LTE basestation



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OF THE WORLD

# China Applications

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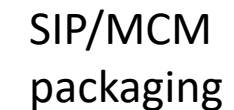
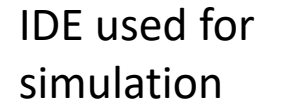
Custom LTE Modems

NB-IoT with AI

GPS / BeiDou positioning

Broadband Power Line Communications BPLC (China Grid)







# Development and system testing boards for SB3500



Sb3500 chips



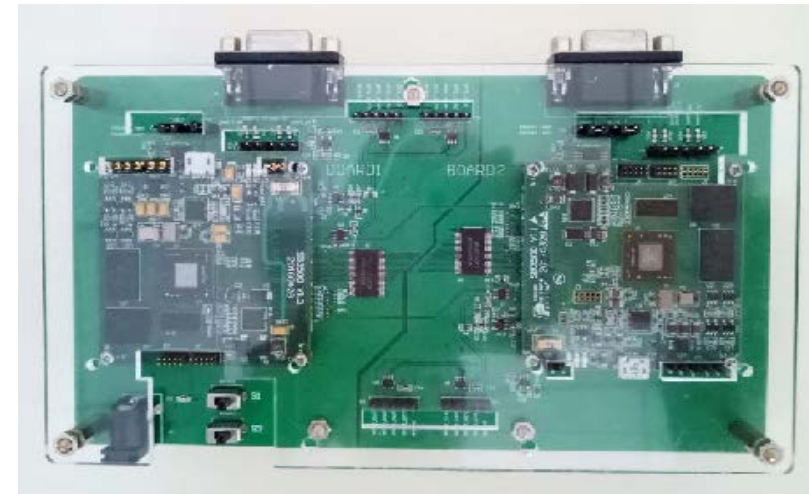
Digital processor board



SDR  
board



RF  
board



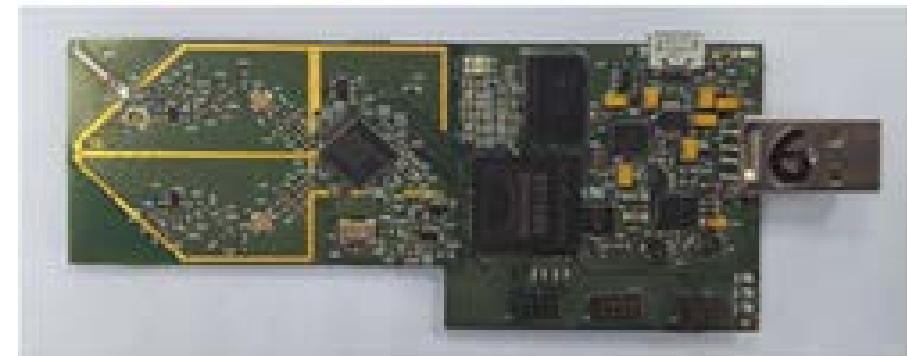
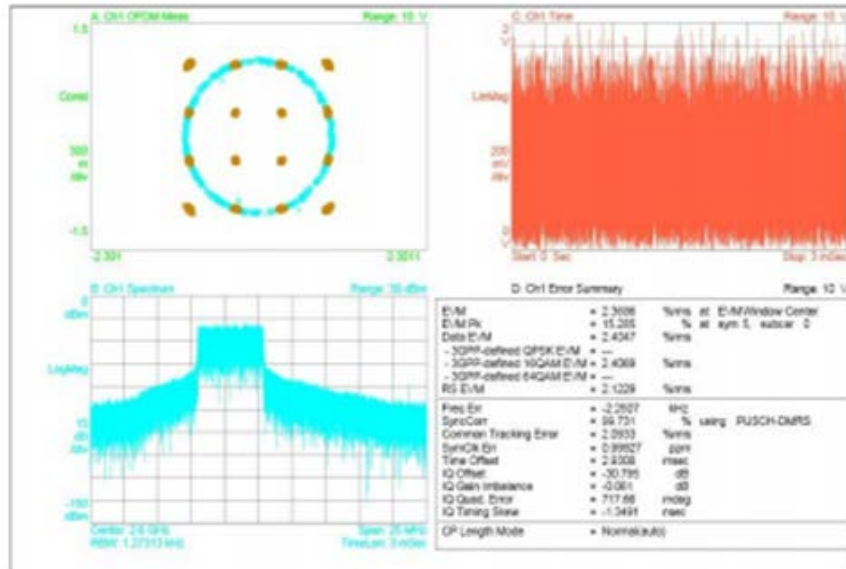
System  
testing  
board

# Custom LTE Modems for UAV's

## 3GPP LTE Extended with

- Special purpose wideband communications system
- Peak: 27Mbps (DL) / 12Mbps (UL)

## Real-time image transmission



# NB-IoT

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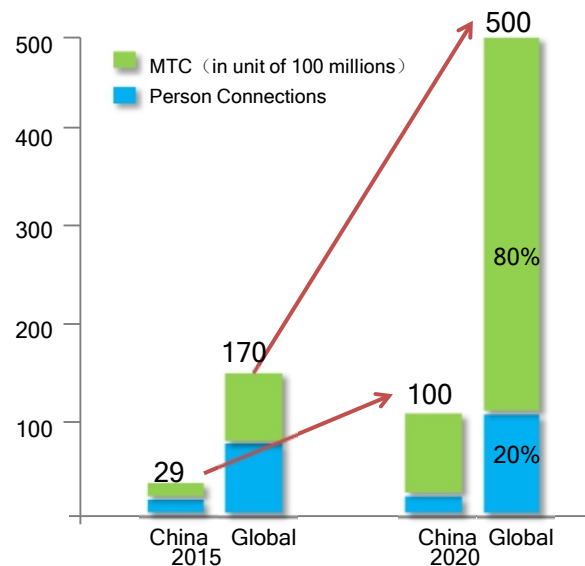


# IoT market is exploding in China

IoT market dramatic growth in 5-10 years, 20% share for Chinese market

Connections:

9 billion MTCs in China in 2020

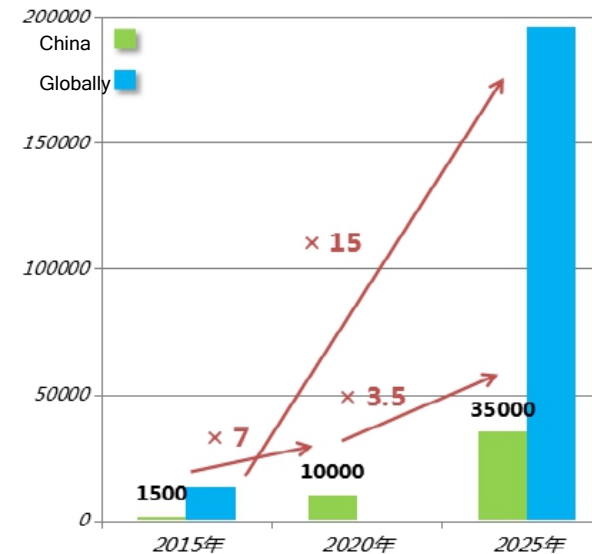


Ref:  
Cisco report in 2013、  
Machina Research in 2015、McKinsey Report

Market size:

19 thousand billions globally in 2025

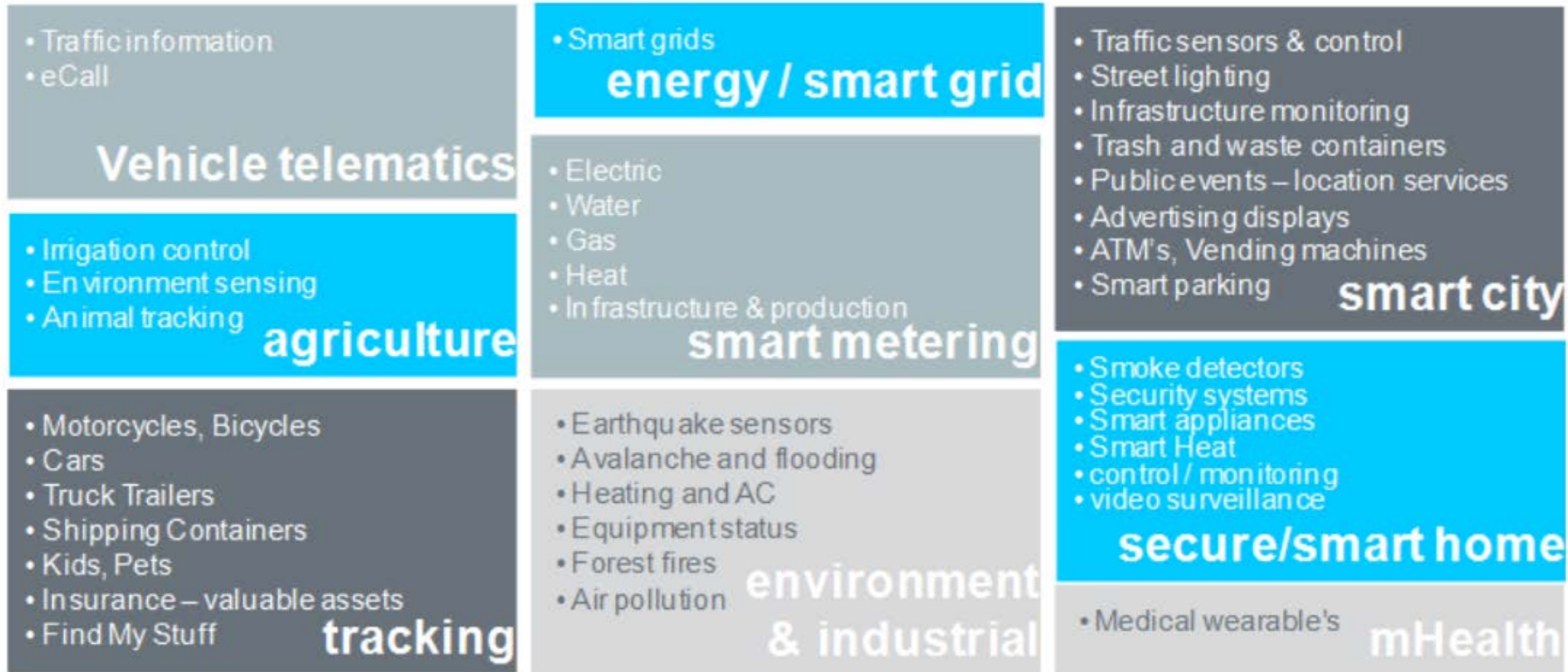
3.5 thousand billions in China



Ref:  
McKinsey Report in July 2015



# IoT Use Cases



# IoT Standards Comparison

|                             | LoRa             | GSM (Rel.8)        | EC-GSM-IoT (Rel.13) | LTE (Rel.8)                         | eMTC (Rel.13)                      | NB-IoT (Rel.13)                                |
|-----------------------------|------------------|--------------------|---------------------|-------------------------------------|------------------------------------|--|
| LTE user equipment category | N/A              | N/A                | N/A                 | Cat.1                               | Cat.M1                             | Cat.NB1  |
| Range                       | <15km            | <35km              | <35km               | <100km                              | <100km                             | <35km  |
| Max. coupling loss          | 155dB            | 144dB              | 164dB               | 144dB                               | 156dB                              | 164dB  |
| Spectrum                    | Unlicensed <1GHz | Licensed GSM bands | Licensed GSM bands  | Licensed LTE bands In-band          | Licensed LTE bands in-band         | Licensed LTE in-band guard-band stand-alone    |
| Bandwidth                   | <500kHz          | 200kHz             | 200kHz              | LTE carrier bandwidth (1.4 – 20MHz) | 1.08MHz (1.4MHz carrier bandwidth) | 180kHz (200kHz carrier bandwidth)              |
| Max. data rate*             | <50kbps (DL/UL)  | <500kbps (DL/UL)   | <140kbps (DL/UL)    | <10Mbps(DL)<br><5Mbps(UL)           | <1Mbps (DL/UL)                     | < <b>28</b> kbps (DL)<br>< <b>63</b> kbps (UL) |

# NB-IoT plus Applications

## SB3500 designed for Cat-1 LTE

- 10 (DL) / 5 (UL) Mbps

## NB-IoT <100kbps

- Minimal SB3500 utilization
- Supports additional simultaneous applications

## Applications

- Location/positioning: GPS/BeiDou
- Additional (simultaneous) communications links
- Deep neural networks

## Partner developed AI SDK for SB3500

- CNN and RNN
- Video object recognition
- Voice detection
- Public release 1Q2018



NB-IoT Development board

# China Grid BPLC

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BROADBAND POWER LINE COMMUNICATIONS



# China Grid Green Energy Initiative



Last mile using BPLC

Electricity gather system

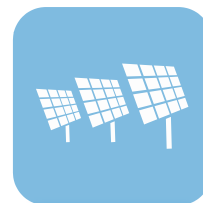
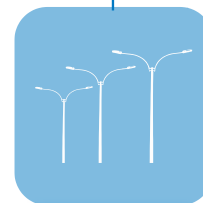
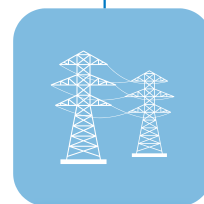
Smart city

Home automation

Building Automation

Energy Management

New energy system

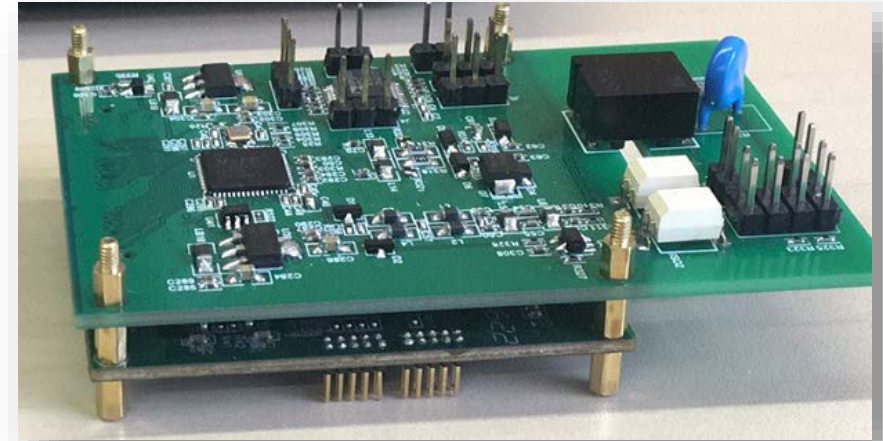




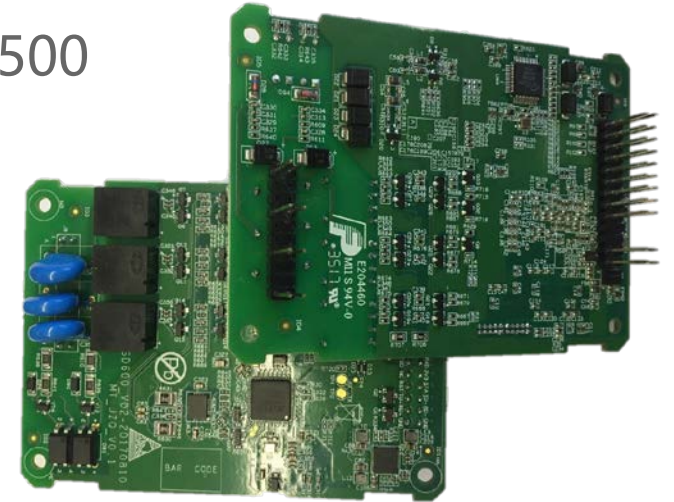
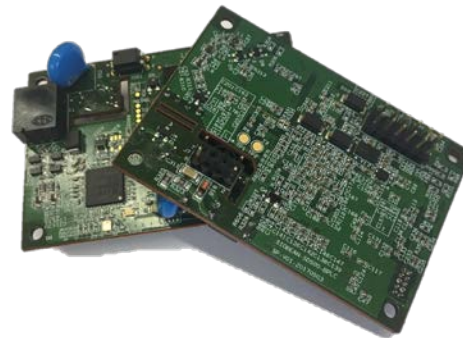
# SDR based BPLC Products

## SDR based BPLC development platform

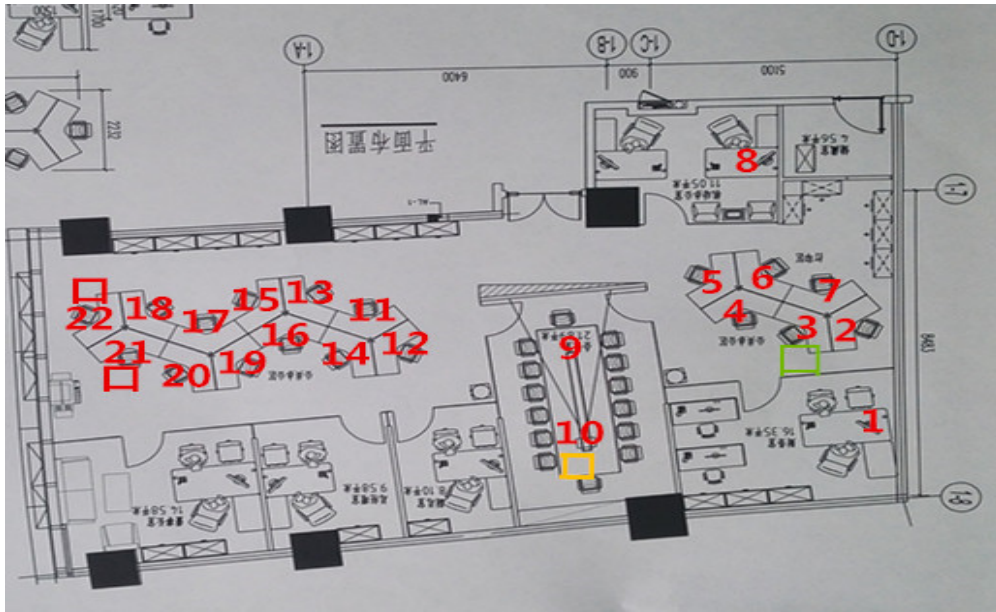
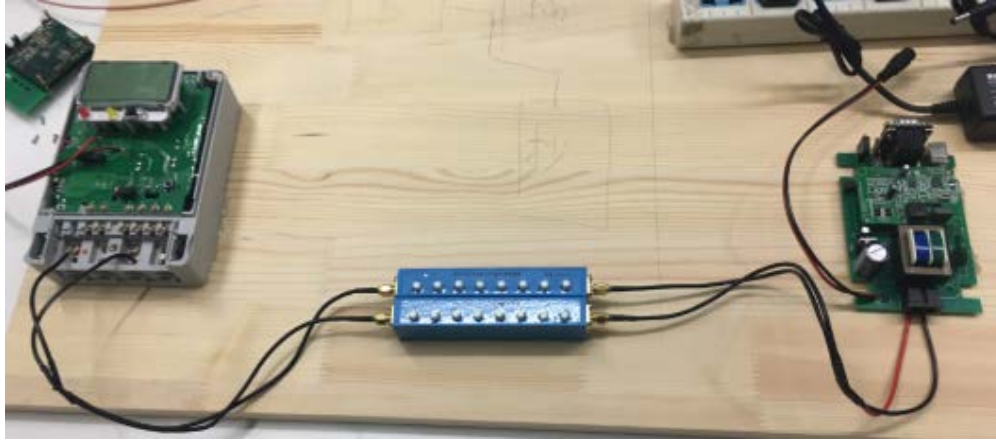
- BPLC PHY Transmissions
- BPLC Protocol Stack
- BPLC Testing Environment
- BPLC Conformance Testing
- BPLC Mesh Networking



Modules designed with SB3500



# Indoor Testing of BPLC

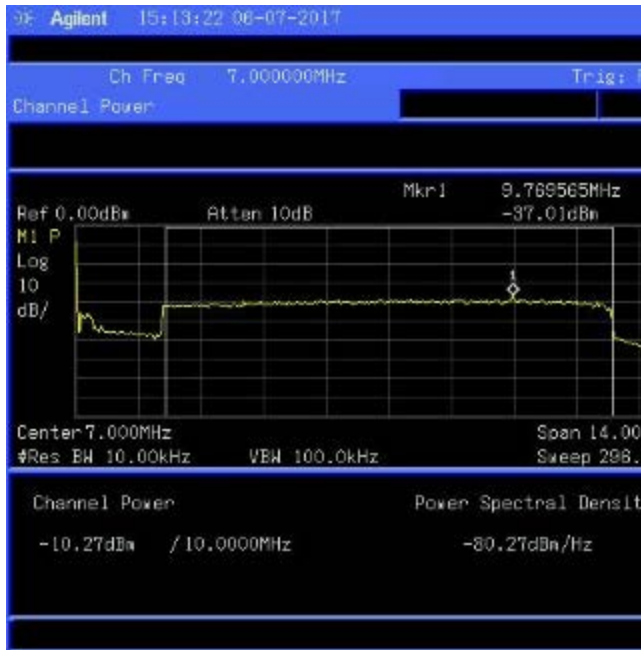


|             | 测试次数 | Success rate,<br>vendor 1 | Success rate,<br>vendor 2 | SB3500  |
|-------------|------|---------------------------|---------------------------|---------|
| Location 4  | 1000 | 99.90%                    | 99.60%                    | 91.42%  |
| Location 5  | 1000 | 99.80%                    | 99.20%                    | 99.75%  |
| Location 6  | 1000 | 100.00%                   | 100.00%                   | 99.31%  |
| Location 7  | 1000 | 36.00%                    | 99.90%                    | 99.87%  |
| Location 8  | 1000 | 32%                       | 99.20%                    | 100.00% |
| Location 9  | 1000 | 30%                       | 99.90%                    | 100.00% |
| Location 10 | 1000 | 97.20%                    | 97.00%                    | 79.22%  |
| Location 11 | 1000 | 99%                       | 96.70%                    | 90.06%  |
| Location 12 | 1000 | 69.80%                    | 99.80%                    | 90.83%  |
| Location 13 | 1000 | 96.00%                    | 99.10%                    | 97.08%  |
| Location 14 | 1000 | 87.80%                    | 97.30%                    | 89.07%  |
| Location 15 | 1000 | 79.80%                    | 95.70%                    | 99.29%  |
| Location 16 | 1000 | 75.30%                    | 98.80%                    | 81.07%  |

Tested on June of 2017



# Outdoor Testing of BPLC



|            | Testing times | Success rate, vendor 1 | Success rate, vendor 2 | SB3500  |
|------------|---------------|------------------------|------------------------|---------|
| Location 2 | 1000          | 32.59%                 | 63.65%                 | 99.56%  |
| Location 3 | 1000          | 99.20%                 | 99.60%                 | 100.00% |
| Location 4 | 1000          | 100.00%                | 99.80%                 | 100.00% |



# Support

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# SDR Website for SB3500, www.sdrerc.com



## SDB3500\_01 (无线系统开发板)

所属分类: 开发套件

SDB3500\_01开发套件是无线系统开发板 (Software Defined Radio Board for SB3500) 和一块RFB9361实现通用无线通信系统的软件无线电实



## RFB9361\_00 (AD9361射频基板)

所属分类: 开发板

RFB9361\_00板主要基于AD9361的收发系统等实现过程。DPB3500\_01板结合RFB9361实现方案。



## DLB3500\_01 (数字环回开发板)

所属分类: 开发套件

DLB3500\_01开发套件是数字环回开发板 (Digital Loop Back Board for SB3500) 和一块DLB3500\_01开发套件。通过硬件PSD数据端口直连, 测试, 使得开发者可以脱离射频等其他



## Sandblaster 开发套件

所属分类: 开发套件

基于SB3500芯片和Sandblaster @ IDE的环境。它集成了Flash和DDR存储器, 以及连



# Summary

## Multithreaded DSP baseband processor

- High-performance and low-power

## Sophisticated compiler technology

- Automatically generates DSP operations
- Automatically multithreads applications

## Reconfigurable Communications Software

- LTE, WiMax, WiFi, GSM/GPRS, GPS

## Multimedia Software

- Analog TV (s-video), MP3, MPEG4/H.264

## Alive and well with new China-based applications

- Custom LTE
- Location / positioning
- NB-IoT
- BPLC

