AST Connectivity
Digital Communication

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June 15, 2010
Outline

- STMicroelectronics introduction
- Advanced System Technology - AST
- AST Connectivity team
  - Team mission
  - Standardization committees participation
  - Digital Base-Band activities:
    - Algorithm Investigation
    - Architecture Exploration
STMicroelectronics

- Global semiconductor company
- Mission: to offer strategic independence to our partners worldwide, as a profitable and viable broad range semiconductor supplier

ST Q1 2010 sales 100%=US$ 2.325 billion
AST Connectivity team

- **Mission:** be the competence center for algorithms and architecture modeling of digital communication systems at PHY and MAC layers

- **Emphasis:**
  - improve the know-how on next generation communication systems
  - define and propose proprietary IPs

- **... also by means of:**
  - direct participation to selected normative standardization committees
  - collaborations with leading edge universities and research centers
The Academic Network

Berkeley
UCLA
USC
Honk Kong

ESA
IMEC
LETI
ETH
Uni Padova
Uni Pavia
Uni Bologna
Uni Pisa
Uni Lecce

Poli Milano
Poli Torino

STMicroelectronics
Project History

a) Contributed to Turbo Code
b) Supported LDPC development

RX Baseband: Channel Coding test chip with Viterbi & Reed-Solomon

Complete TX FPGA

3G Turbo Code Outer Modem Stream Processing Engine

TX / RX ref chain (MIMO enabled)
MIMO ML detection algo & RTL Support to in house MAC engine dev

IEEE 802.11ad
60 GHz

DVB-RCT

802.11a

DVB-S2

3G-UMTS

IEEE 802.11n

HSDPA

802.11e

DVB-T

HomePlug AV

80G Optical fiber

Code Generation (scrambling, spreading & Freq. domain Equalization)

IEEE 802.11p

MoCA

1995 2000 2005 2010

Today
Standardization committees

- **High Throughput WLAN** IEEE 802.11n and also:
  - Relevant new IEEE 802.11 Standards, Task Groups, Study Groups

- **Mobile WLAN** IEEE 802.11p and IEEE 1609, ETSI
  - V2V and V2I Communications

- **Home Plug AV2**
  - Power Line Modem

- **WGA (Wireless Gigabit Alliance) consortium** –
  - IEEE 802.11ad and .11ac – 802.15.3c – WirelessHD
    - 60GHz & <6GHz

- **Wireless Innovation Forum for SDR & Cognitive Radio**
IEEE 802.11 standards family address Wireless Local Area Networks (WLAN)

802.11p: mobile broadband application (vehicle-to-vehicle, V2V and vehicle-to-infrastructure, V2I)
  - Judged the key enabling access technology across EU and USA (and probably Japan), though complementary and coexisting with other like e.g. cellular communication
  - Purpose is to standardize V2V and V2I communications in 5.9 GHz bandwidth (5.85-5.925 GHz).
  - 10 MHz bandwidth, maximum data rate of 27 Mbps.
  - Very short latencies
  - Expected final approval by 2010
Introduction: vehicular channel model

Vehicular Environment: the wireless propagation properties may change over possibly short data packets

- Wireless channel: discrete multi-path time-varying model
- Longer delay spread than indoor ch
- Independent per tap Doppler effect (Jakes spectrum)

\[ h(kT, nT_c) = \sum_{l=0}^{L_{ch}-1} h_l(kT) \delta(nT_c - lT_c) \]

- \( L_{ch} \) is the total number of paths
- \( B = 1/ T_c \) transmission bandwidth
IEEE 802.11p system block diagram

TX

Source Bits → CC Encode → Interleaver → Mapper → IFFT / GI ins. → Upsample / Filter → D/A

RX

Demapper / Bit LLR → Equalizer → GI removal / FFT → Synch → GI removal / FFT → A/D

DD channel estimator

Deinterl. → Viterbi Dec. → Decoded Bits

CHANNEL

STMicroelectronics
SDR & Cognitive radio

Cellular
- LTE
- HSPA
- WCDMA
- CDMA 1x EV-DO
- GPRS

Broadcasting
- DVB-H
- FM-RADIO
- MBMS
- DAB

Hot-spot
- WIMAX
- UMA
- WLAN
- 60GHz
- Bluetooth
- UWB

Proximity
- RFID
Software communications platform

- Technology is now getting mature enough to allow introducing no significant penalties in terms of area, power and performance when compared to custom hard-wired solutions.
- Current offer is:
  - typically already proven with W-CDMA, CDMA2000, TD-SCDMA, WiFi.
  - targeting mainly mobile (WiMAX, LTE), estimated tens of Gops.
  - supposed to be suitable for MIMO 11n, DVB-H/T, GPS, Wireline... (multi-mode).

- To shorten development time
- To increase architecture lifetime with respect to
  - Emerging communication technologies
  - Silicon technology scaling
- To deal with Multiple Wireless Standards coexistence (4G)
Current implementation covers the following waveforms:

- Multi-mode 11a/WCDMA Frequency Domain Equalizer
- IEEE 11a/p PHY
- MIMO ML-Detection
- Multi-mode DVB front-end
- Cognitive-radio. Spectrum sniffer for ISM bands
HPAV: the backbone of home networking

- HPAV – Audio Video Entertainment (200MBit/s)

- Ongoing development: next gen HPAV 2.0 (1GBit/s)
HPAV modem block diagram

Source: ©2007 IEEE
Next Generation: HPAV2

- New in-home scenarios arise, including applications requiring high-data rates and demanding QoS, as:
  - Multiple HD video streaming
  - IPTV, both broadcast and unicast
  - Gaming and latency intolerant applications
  - VoIP

- In 2009 HomePlug Alliance started to define next generation power line modems: HPAV 2.0

- 2010 research agenda:
  - HPAV 2.0 standardization active participation
  - Investigation of high throughput features
  - Performance characterization
  - New architecture exploration
MIMO – PLC

- MIMO channel for 3-wire installations:
  - Phase (P)
  - Neutral (N)
  - Protective Earth (PE)

- Signals sent and received differentially between pairs of wires:
  - TX: 3 different possibilities: N-PE, P-N, P-PE. Due to Kirchhoff’s rule only two out of the independent input ports can be used
  - RX: 3 differential reception ports are available
The idea behind MIMO is that the signals on the transmit points at one end and the receive points at the other end are “combined” in such a way that the quality (error rate) or the spectral efficiency (bits/sec/Hz) of the communication will be improved:

- **multiplexing gain**
  - different streams are sent over the different transmit ports
  - the throughput directly increases

- **diversity gain**
  - the same stream is sent over the different transmit ports
  - the reliability directly increases
Knowledge about MIMO-PLC is still limited

Stage proposal covers:

- MIMO PLC system definition in the HPAV2 Technical Working Group:
  - MIMO techniques suitable for power line communication
  - Modulation and coding schemes
- MIMO receiver algorithms design: synchronization, channel estimation and detection
- Investigation of performance vs complexity tradeoff
Introduction: what is 4G?

- **4G** term is used since several years and assumed many (and often vague) meanings...
- Meaning #1: fourth generation cellular standards (successor of 2G and 3G).
  - Pre-4G technology 3GPP Long Term Evolution (LTE) is often named 4G but the specifications do not comply last 4G requirements
- Meaning #2: broader meaning, convergence of different broadband wireless access communication systems, likely a combination of WiMax and Wi-Fi
- Recently, ITU started standardization effort to define a unique standard for 4G ⇒ IMT-advanced (by ITU-R): **100 Mbit/s** for high mobility and **1 Gbit/s** peak data rates for low mobility
- Recently (October 2009) technology proposals submitted to ITU-R as 4G candidates. Main two selected technologies so far:
  - **LTE Advanced** standardized by the 3GPP
  - **802.16m** standardized by the IEEE (Mobile **WiMax** Release 2)
Our team active in some of 4G key technologies, including:
- **OFDM/OFDMA**
- **MIMO** (key enabler for very high spectral efficiencies)
- **SDR** (software defined wireless communication protocols instead of hardwired implementations)

Interested in analysis/modeling of LTE-Advanced
- LTE Release 10 & beyond (LTE-Advanced), in progress by 3GPP ⇒ smooth evolution of LTE standard
- Peak data rate DL: 1 Gbps, UL: 500 Mbps
- MIMO
- Transmission bandwidth: > 70 MHz in DL and 40 MHz in UL
- Spectrum flexibility: Support of scalable bandwidth (>20 MHz, potentially up to 100 MHz) and spectrum aggregation
Stage proposal: LTE modeling

- LTE (Long Term Evolution) is the last step towards in-cell technology towards 4G ⇒ investigation and modeling of LTE is necessary to face 4G
- Employs MIMO and OFDM
  - OFDMA in Downlink (DL)
  - Multi-User-MIMO for DL and Uplink (UL) (2x2, 4x4)
  - Single-Carrier Frequency-division Multiple Access (SC-FDMA), also called DFT-precoded OFDM, for UL
- DL peak rates of at least 100 Mbps, UL of at least 50 Mbps, low latency, scalable carrier bandwidths (from 20 MHz down to 1.4 MHz), supports both frequency division duplexing (FDD) and time division duplexing (TDD)

- Stage proposals: contribute to the definition of LTE sw library for UL and DL i.e. ⇒
  - Activity #1: (Matlab) modeling and performance simulation of single-user MIMO DL
  - Activity #2: (Matlab) modeling and performance simulation of SC-FDMA for UL
  - Both activities require literature analysis and modeling of suitable channel models
Activity proposal summary in AST Connectivity

- Within AST Connectivity stage/internships opportunities available for pre-graduate and graduate students
  - Conditions: up to 12-month contract, monthly compensation, meal included.

- Our current topics:
  - HPAV2: MIMO-PLC / contact: raffaele.riva@st.com
  - LTE / 4G / contact: massimiliano.siti@st.com
  - Software communications platform / contact: daniele.loiacono@st.com

- Within STMicroelectronics: open positions for graduate students available on www.st.com
  - ST Microelectronics HR contact: Ilaria Cattaneo, email: recruitment.agrate@st.com
Thank you