Departamento de
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Real-time validation of a SDR implementation of TDD WiMAX Standard

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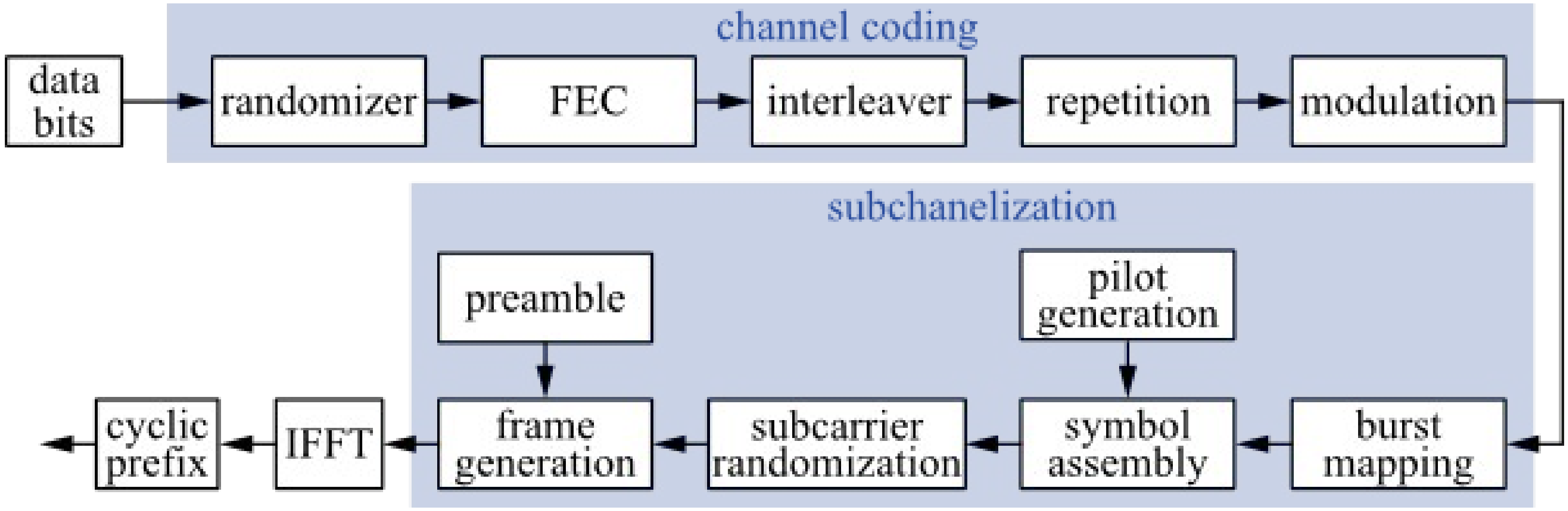
Introduction

- WiMAX is a communications standard based on the work of the IEEE 802.16 working group.
- WiMAX rapidly evolved to support communications in mobile environments and relay-based networks.
- In 2012, WiMAX adopted an advanced air interface to face the challenges of the so-called 4G communications.
- Scalable Orthogonal Frequency-Division Multiple Access (SOFDMA) is at the core of its transmission scheme.
- This work has been partially supported by Indra Sistemas S.A. and Spanish Ministry of Defence under the COINCIDENTE Program.

WiMAX profile	Channel Bandwidth [MHz]	Sampling frequency [MHz]	FFT size
1	3.5	4	512
2	5	5.6	512
3	7	7	1024
4	8.75	10	1024
5	10	11.2	1024

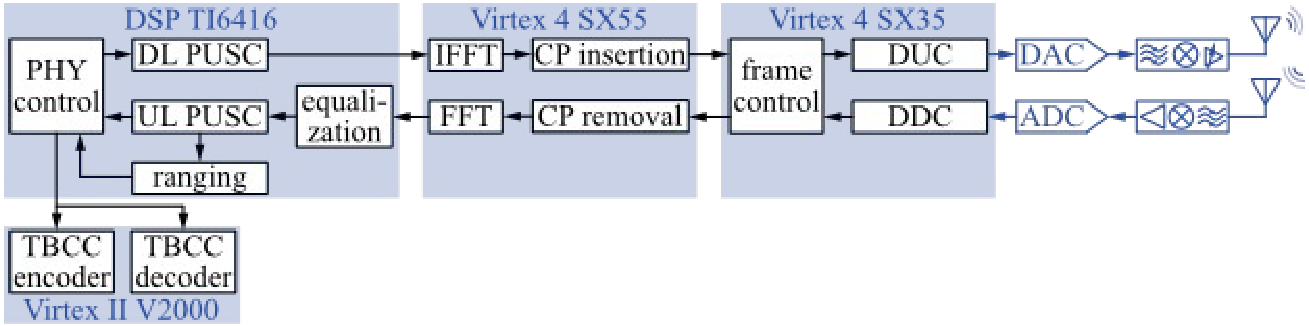
Mobile WiMAX Physical Layer

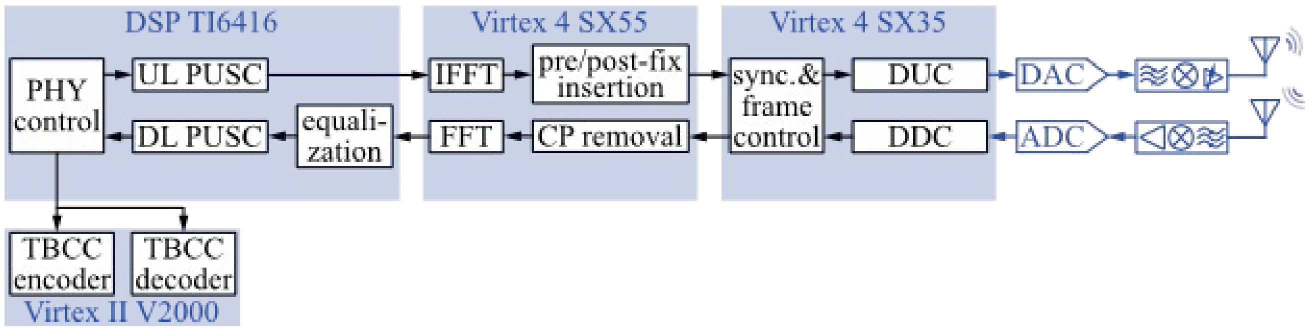
- Different channel coding algorithms are supported: TBCC, BTC, CTC, LDPC.
- Modulation supports different constellation sets: QPSK, 16-QAM and 64-QAM.



Proposed system architecture

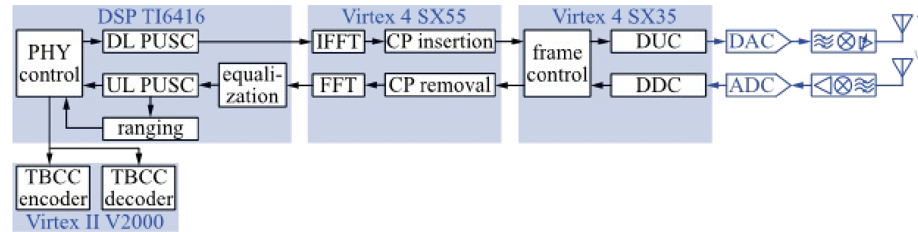
- The implementation described is based on the mandatory parts of the Mobile WiMAX Physical Layer.
- It employs the OFDM-TDD structure, PUSC permutation scheme both in downlink and uplink subframes, ranging and channel coding based on TBCC.

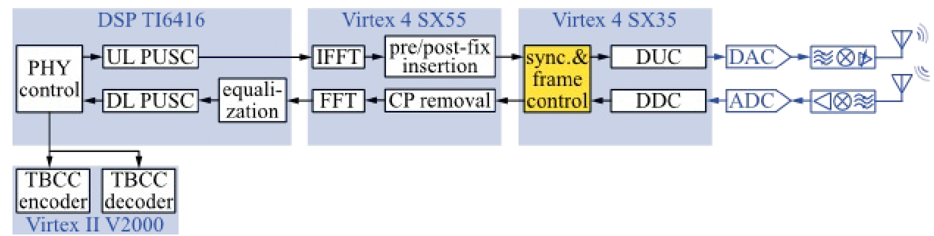


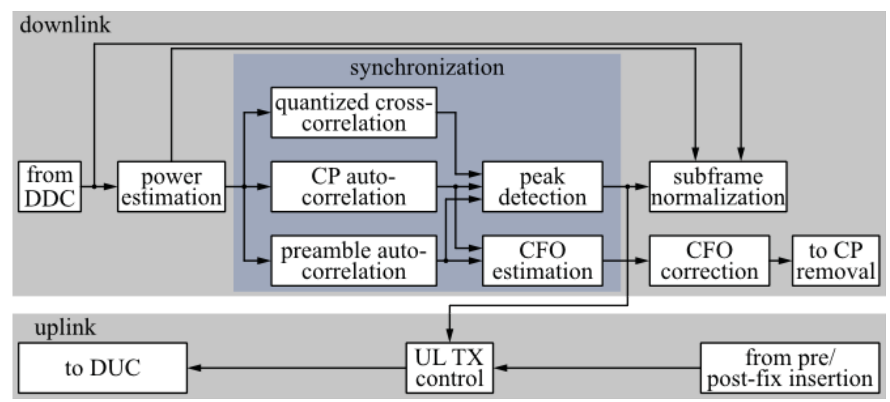


Proposed system architecture

- Downlink synchronization module implements the algorithms of frame and symbol detection in the mobile station.
- Correlation properties exhibited by the preamble defined in the standard, as those found in OFDM symbols with cyclic prefix, are exploited to complete this task.
- Frequency offset estimations are also computed, and received signal is corrected before FFT module.

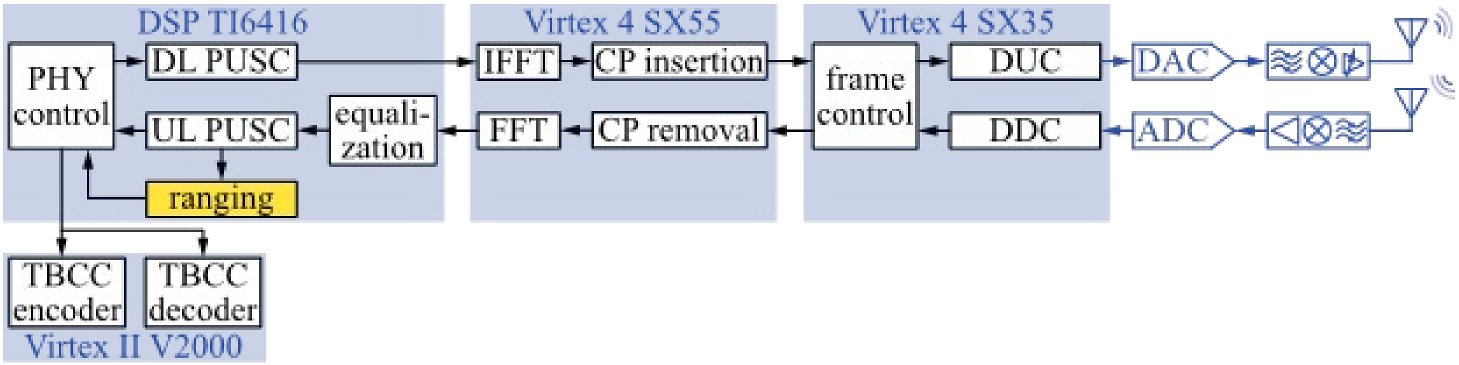


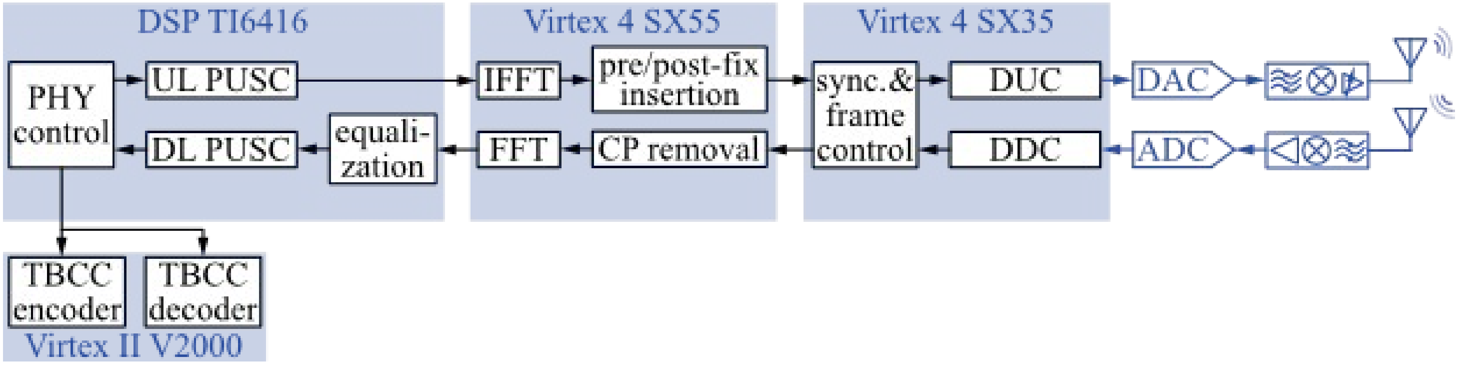




Proposed system architecture

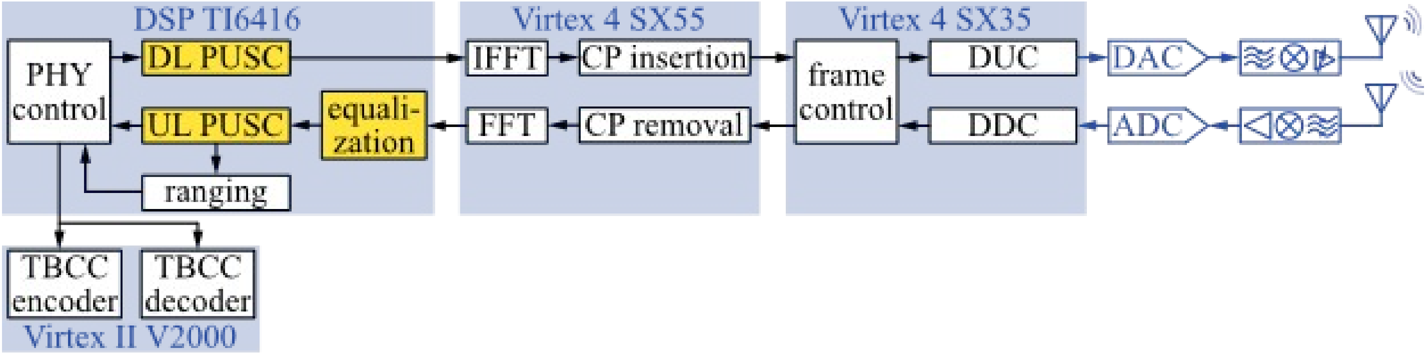
- Ranging protocol allows mobile stations to send fixed sequences to the base station.
- Base stations use this signals to estimate the uplink synchronization parameters.

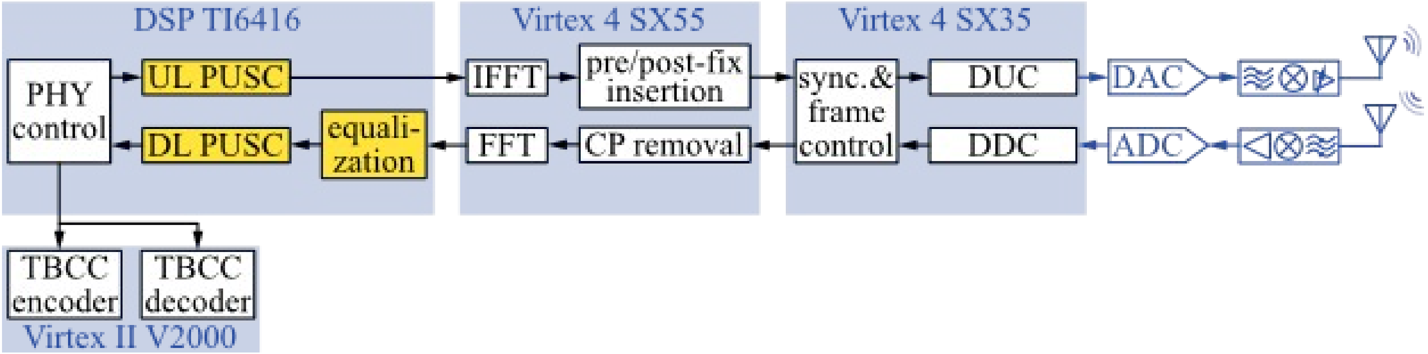




Proposed system architecture

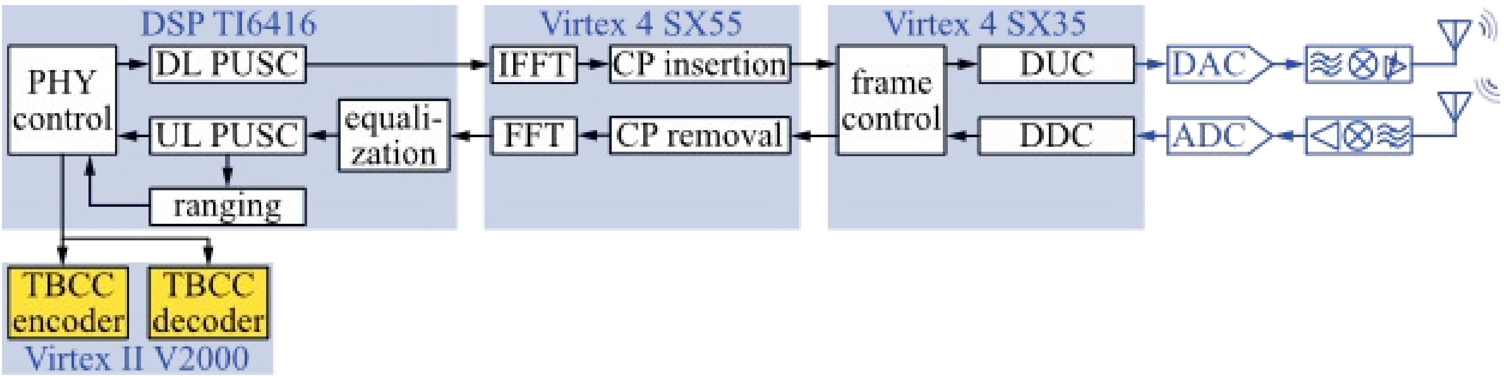
- Subchannelization involves interleaving and randomization of subcarriers.
- Channel estimation and equalization is done by inverting the pilot subcarriers and linearly interpolating the computed values.

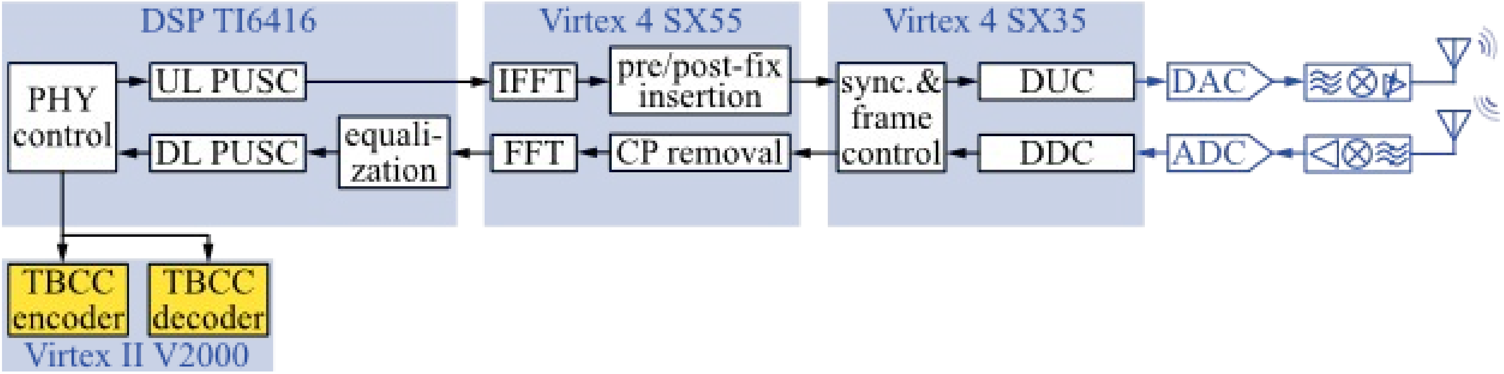




Proposed system architecture

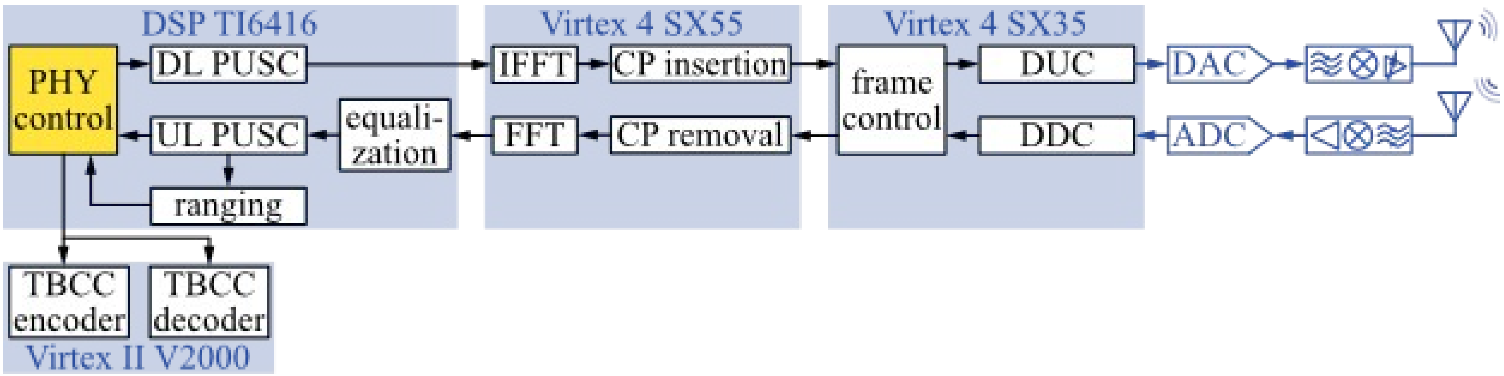
- Channel coding module uses the TBCC coding scheme.
- This module also implements a CINR estimator employing a soft decisor to estimate the transmitted symbols.

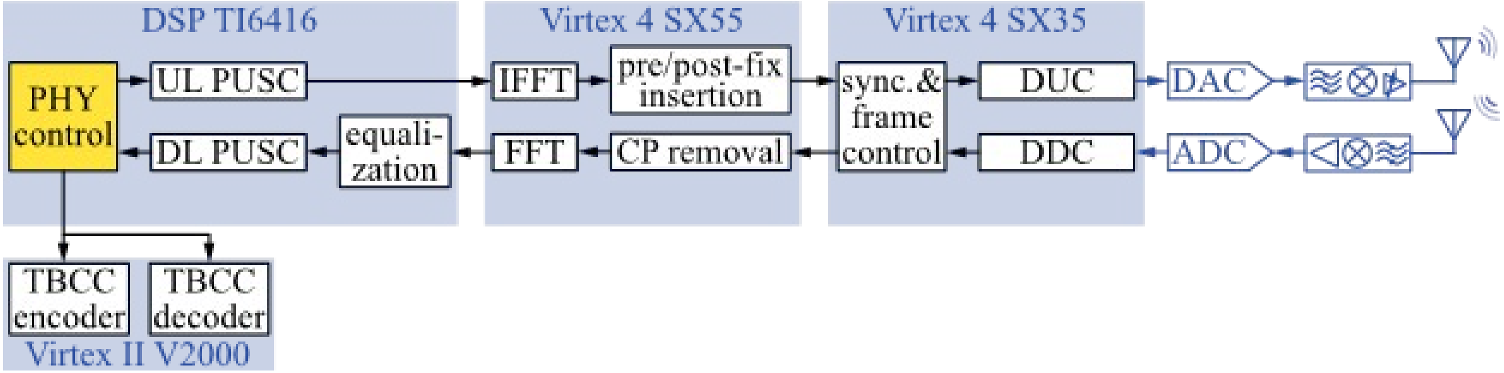




Proposed system architecture

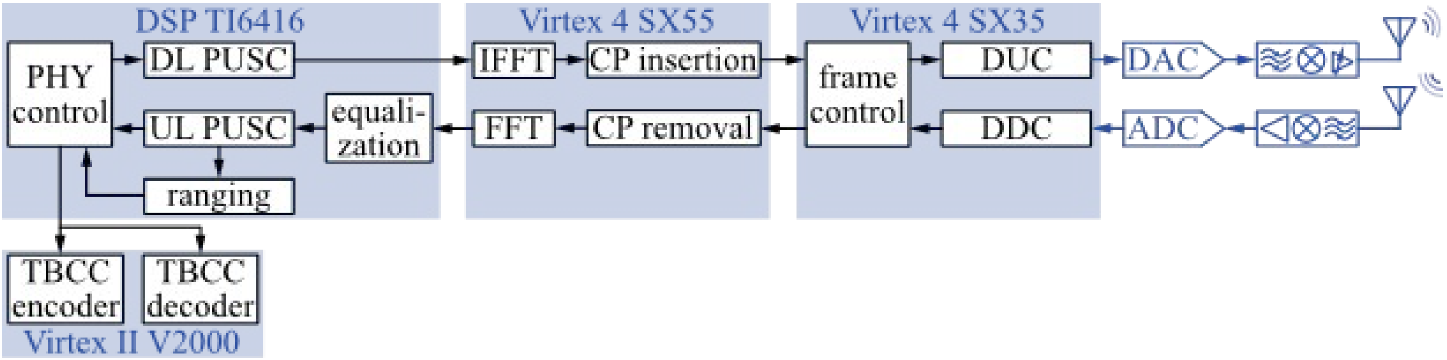
- Separation between MAC-level and PHY-level processing is obtained by the so-called Service Access Point (SAP) specification defined by Intel.

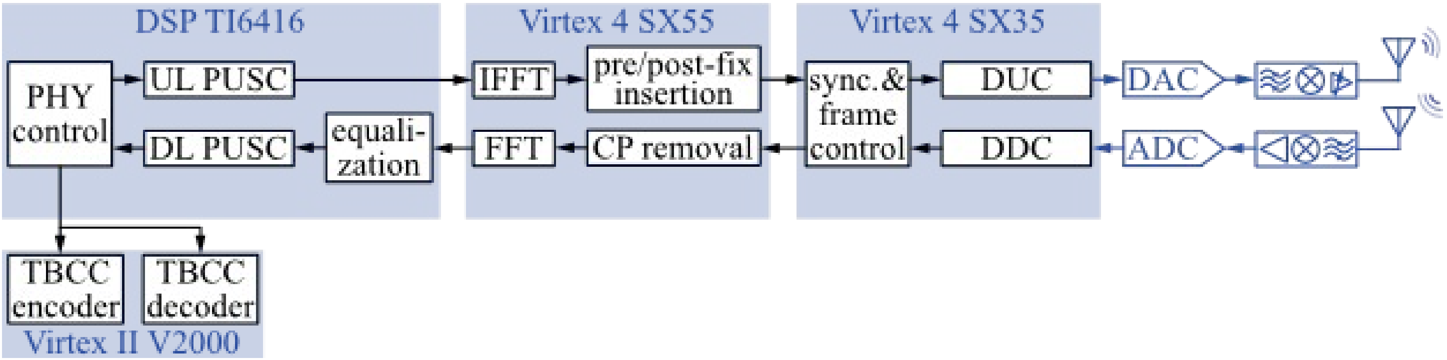




Hardware description

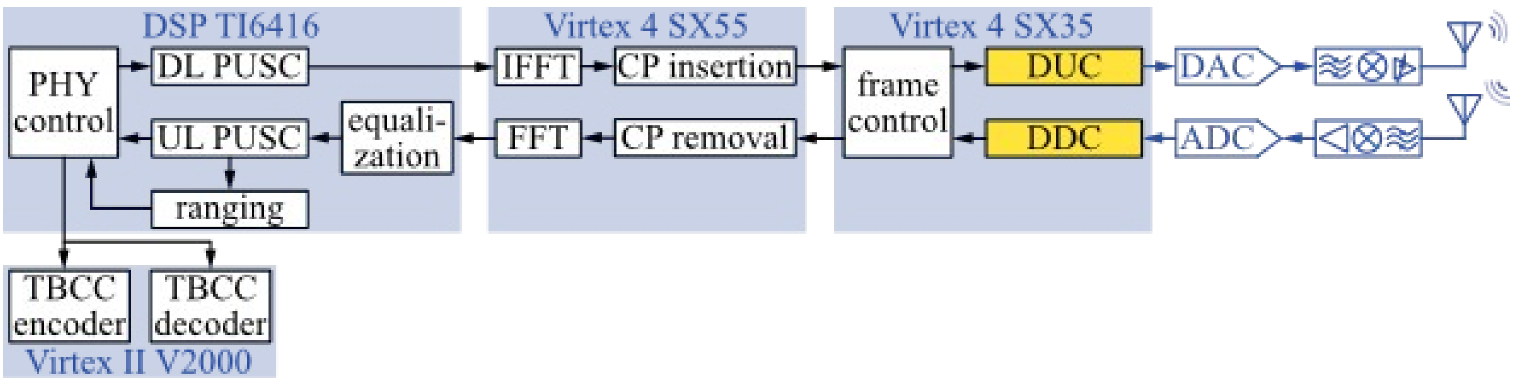
- The implementation was based on COTS components.
- Data exchange between hardware modules is achieved using proprietary buses: 400 MB/s data buses and 20 MB/s control buses.

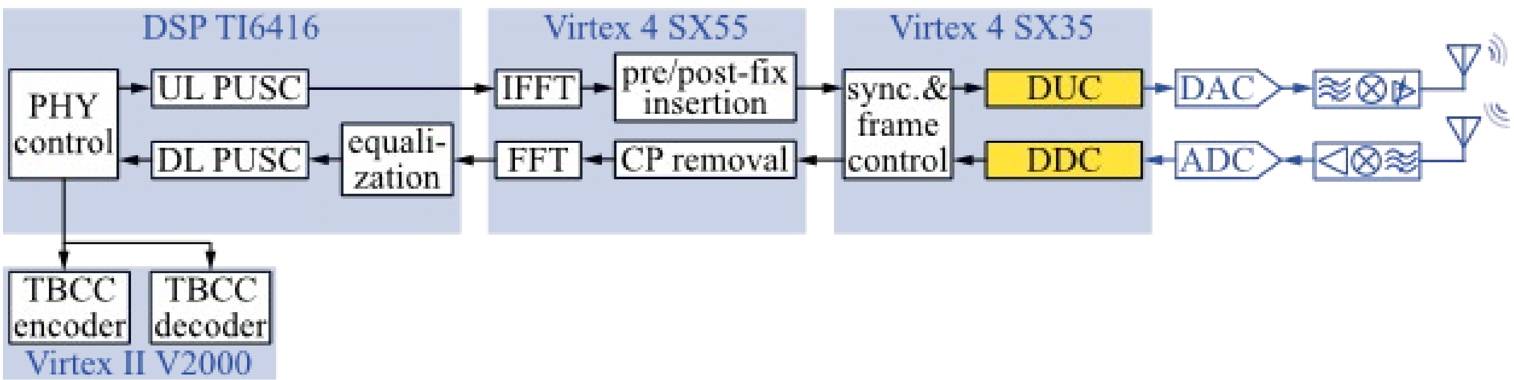




Hardware description

- Each WiMAX profile requires a different configuration of the up/down conversion filters.
- Different FPGA bitstreams are generated for each profile.





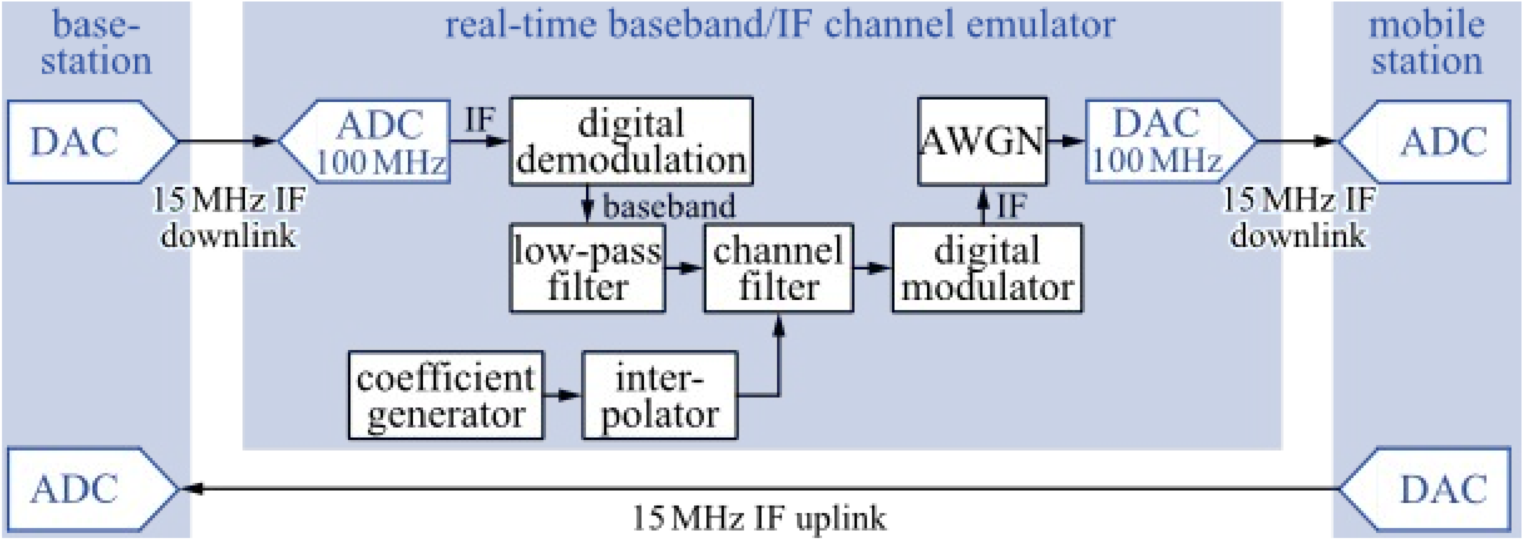
Resource utilization

Base station	Virtex-II	Virtex-4 SX55	Virtex-4 SX35	Mobile station	Virtex-II	Virtex-4 SX55	Virtex-4 SX35
Slice	94%	56%	41%	Slice	94%	59%	99%
LUT	62%	37%	26%	LUT	62%	40%	73%
RAMB16	92%	25%	23%	RAMB16	92%	35%	27%
Mutipliers	3%	22%	12%	Mutipliers	3%	22%	36%

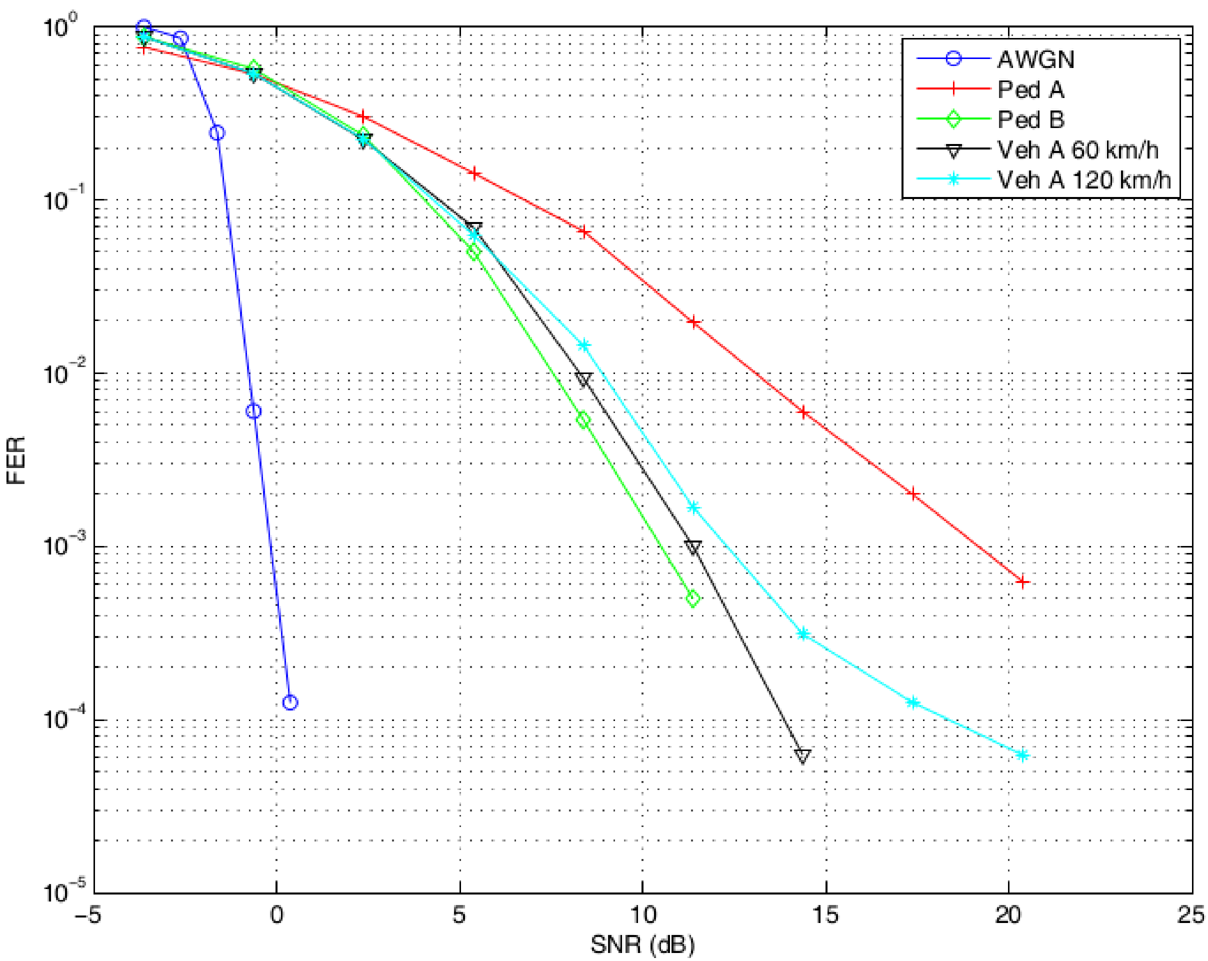
- The system prototype was implemented using automatic code generation tools such as Xilinx System Generator.
- Usage of FPGA resources was not minimized because it was out of the scope of this work, although the system is completely functional.

Performance evaluation

- Evaluation of the system was done with the help of a channel emulator, implemented on a Virtex-4.
- Three scenarios were considered:
  – Pedestrian A (3 km/h)
  – Pedestrian B (3 km/h)
  – Vehicular A (60-120 km/h)

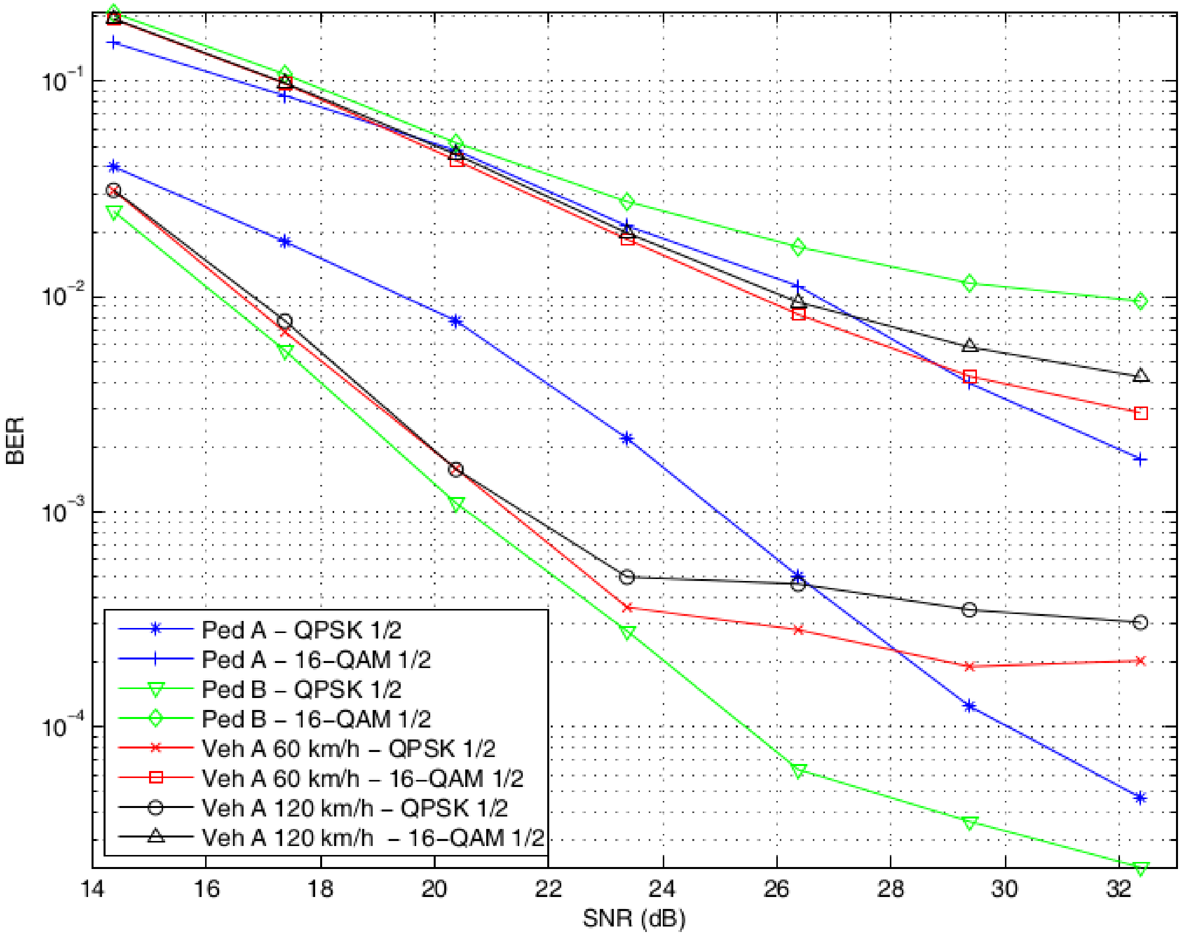


Performance evaluation



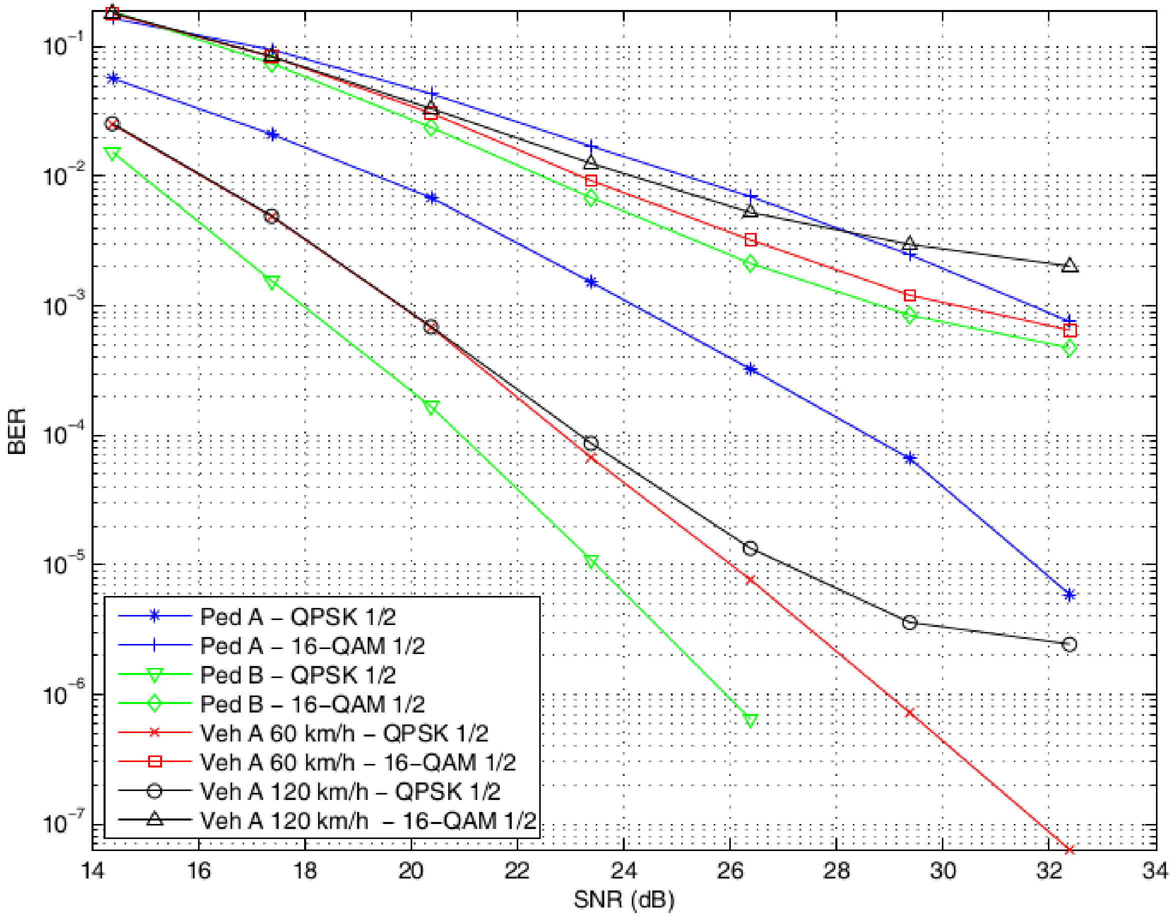
Frame detection rate	
Bandwidth	3.5 MHz
FFT size	512

Performance evaluation



BER Downlink	
Bandwidth	8,75 MHz
FFT size	1024

Performance evaluation



BER Uplink	
Bandwidth	8,75 MHz
FFT size	1024

Conclusion

- We have proposed a design and implementation of a real-time, bi-directional TDD physical layer compliant with WiMAX standard.
- The SDR architecture consists of COTS modules based on FPGAs and DSPs.
- The system was tested with a channel emulator of mobile and vehicular environments.
- Future work will be devoted to extend this design to support the Advanced Air Interface defined in IEEE 802.16m.
- Resource optimization of the system will be further studied in order to get an efficient final implementation.

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