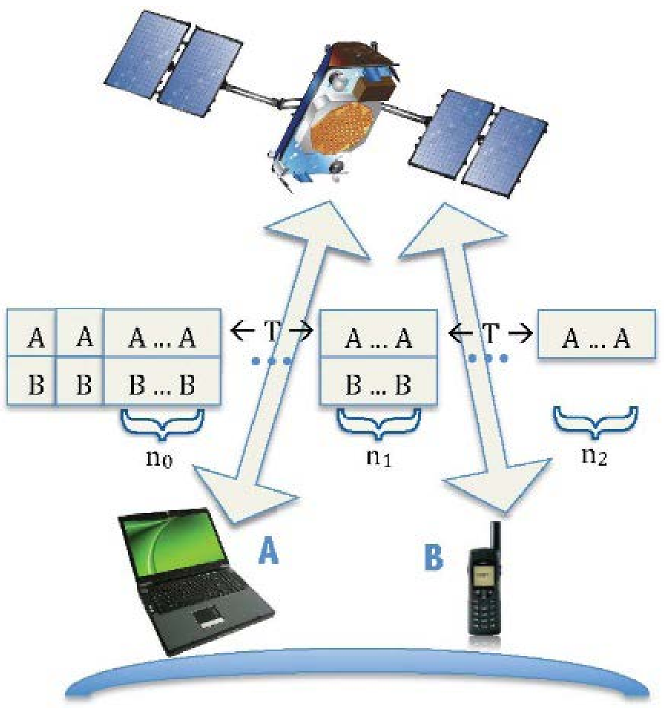
Multi-Packet Detection Techniques for Satellite Networks

MPSat addressed the design of high bitrate Low Earth Orbit satellite systems capable of providing improved QoS guarantees to an extended set of ground terminals. It developed new multi-packet reception solutions, which applied cross-layered optimizations to the physical, data link and routing layers' protocols. The project included analytical modelling and the development of simulation tools.



Main Project Team	
Luis Filipe Lourenço Bernardo	**RS-Lx**
Rui Miguel Henriques Dias Morgado Dinis	RS-Lx
João Carlos Marques Silva	RS-Lx
Rodolfo Alexandre Duarte Oliveira	RS-Lx
Paulo Miguel de Araújo B. Montezuma de Carvalho	RS-Lx
Francisco António Bucho Cercas	RS-Lx
Paulo da Costa Luis da Fonseca Pinto	RS-Lx
Funding Agencies	
FCT	**36,871€**
Start Date	01/02/2010
Ending Date	31/07/2013
Indicators	
Journal Papers	17
Conference Papers	58
Patents	2
Concluded PhD Theses	5
Concluded MSc Theses	20

Two Main Publications

M. Luzio, R. Dinis, P. M. Montezuma, **Pragmatic Frequency Domain Equalization for Single Carrier with Offset Modulations**, IEEE Transactions on Wireless Communications, Vol. 12, No. 9, pp. 4496 - 4505, September, 2013

F. Ganhão, R. Dinis, L. Bernardo, R. Oliveira, **Analytical BER and PER Performance of Frequency-Domain Diversity Combining**, Multipacket Detection and Hybrid Schemes, IEEE Transactions on Communications, Vol. 60, No. 8, pp. 2353 - 2362, August, 2012

PROJECT WEBPAGE URL
http://tele1.dee.fct.unl.pt/mpsat

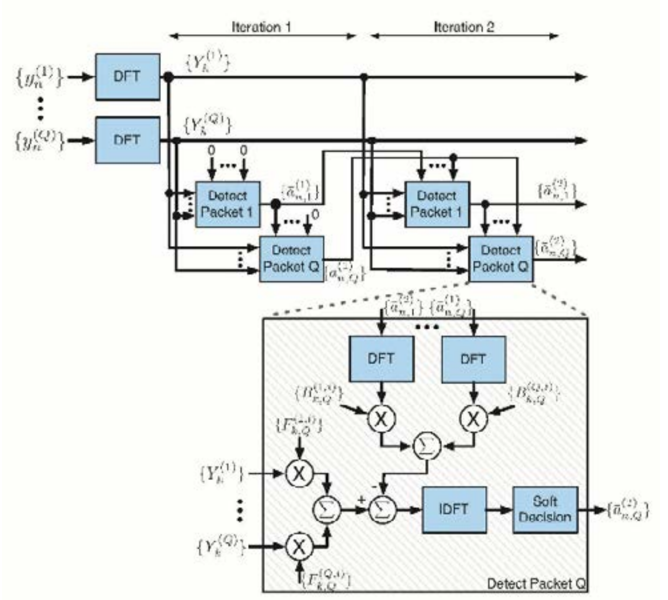


Fig. 1 SC-FDE MPR receiver

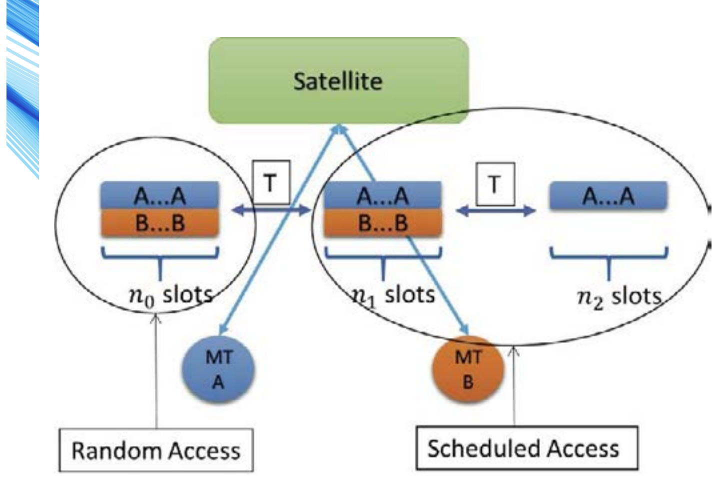


Fig. 2 Satellite Random – Network Diversity Multiple Access MAC protocol

GENERAL MOTIVATION AND OBJECTIVES

LEO (Low Earth Orbit) satellite systems failed to succeed due to the poor services offered compared to the terrestrial cellular services, in spite of the global coverage provided. The objective of this project was to increase the sustained available bit rate on a LEO satellite system in each direction for small-sized ground terminals, with low power consumption and employing antennas with reduced directivity.

CHALLENGE

Due to the large distance between the terminal and the LEO satellites, the signal suffers a very high attenuation. High spectral, power and energy efficiencies are required to have direct communication with battery powered handheld devices. Propagation delay is also higher, and medium access and retransmission control must be designed together with the physical layer, to be able to offer reduced controlled delay and jitter to the end users. Finally, the project evaluated how to connect this to other kinds of networks. The research team combined physical layer and data link layer (and above) researchers of IT, to address both issues in an integrated, cross-layered approach.

WORK DESCRIPTION AND ACHIEVEMENTS

The project developed a solution where the physical layer and medium access control (MAC) were designed together to improve the performance of the protocol stack. The approach to match the challenges relied mainly on four contributions that cover the transmitter and receptor design, the data link layer protocol, and cross-layer functionalities:

1) To allow an efficient power amplification and to cope with severe time dispersion effects inherent to having high bit rates and antennas with reduced directivity, we considered the adoption of single-carrier frequency domain equalization (SC-FDE) techniques. New SC-FDE signals with good trade-offs between power and spectral efficiencies and envelope fluctuations were designed, compatible with highly efficient, grossly nonlinear power amplification. The use of powerful error correction codes and error resilient transmission techniques were also considered to reduce the required transmission power.

2) To increase the overall system's spectral efficiency with constant-envelope signals (allowing an increase in the total number of frequency channels available) we considered the spectral overlapping between different channels and we develop suitable receivers.

3) To reduce the number of slots lost in collisions and the required terminal's transmission power we proposed the use of multi-packet reception (MPR) techniques combined with hybrid-automatic repeat request (H-ARQ) approaches to effectively address error handling. After proving the concept, we adapted the incremental symbol spreading provided by MPT and H-ARQ to work with high propagation delays.

4) Finally, to reduce the influence of the orbital movement (and the resulting distance variation) in the perceived link packet error rate we proposed an adaptive cross-layer approach that adapts the packet coding, packet scheduling and ARQ algorithm to the distance to the satellite, the quality of service class, and the total traffic.

This project involved a substantial interaction between MAC and physical layer models, since the MAC layer runs on top of the MPR physical layer. Physical layer simulators were implemented and used to provide outputs for the network simulators implemented (e.g. average bit error rate and block error rate, corresponding statistics, etc.). Cross-layering approaches were modelled by changing the physical layer statistical model used for a given configuration at the system level simulator. Therefore, the simulators model the behavior of the satellite links, allowing an effective validation of the proposed systems.