Self-adaptive embedded technologies for pervasive computing architectures

Sub Project 4: Applicative scenarios

'Wireless communication network based on single, self-adaptive and self-optimized air interface'

Applicative scenario (1)

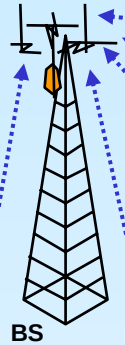
- The proposed applicative scenario concerns an employee of a company (e.g. working in sales department) who is allowed to:
  - operate in networks of variable coverage size,
  - that are governed by different wireless environments (indoor, outdoor),
  - and are serving different levels of capacity i.e. different combinations of topology characteristics (urban, suburban, rural), and different user needs (residential, corporate, nomadic, mobile).
- The wireless terminals of the above scenario will be based on a single, self-adaptive and self-optimized air interface.

Applicative scenario (2)

- The self-adaptive air interface (physical layer) would be based on STC (space time coding) OFDM technology for MIMO channels.
- Recent and future needs of multimedia services over heterogeneous environments, require the identification of the various kinds of users and environments that can be encountered.
- According to the velocity, the users can be classified in fixed and mobile. Mobile users can either be nomadic or vehicular.
- The propagation conditions can be classified as:
  - Line of Sight (LOS): there is a strong enough direct path from the transmitter to the receiver, so that reflections are practically negligible.
  - Poor Line of Sight (PLOS): not strong enough direct path to neglect reflections.
  - Non Line of Sight (NLOS): no direct path, and the receiver signal is composed of a number of reflections or scattered paths.

Applicative scenario (3)

USER: Employee of a company (e.g. in sales department)

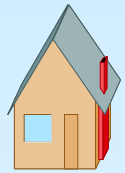


BS

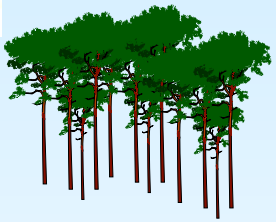
Outdoor-to-outdoor service

SS

Outdoor-to-indoor service



RURAL AREA



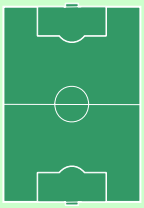
Mobile service

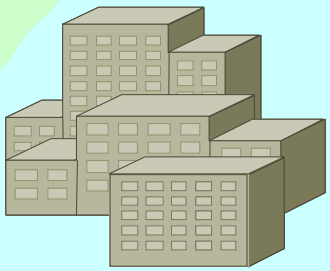
Point-to-point Backhole service

RS

Outdoor-to-outdoor service

SS

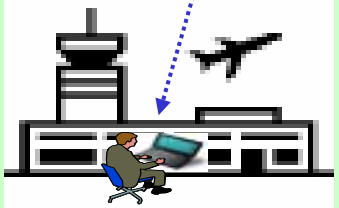




Indoor service

URBAN AREA

Portable Service (nomadic user)



SUBURBAN AREA

Applicative scenario (4)

- The targeted wireless system will combine several characteristics and capabilities of WMANs and WLANs in order to exploit the advantages of the cooperative communication concept.

- Possible service cases of the proposed scenario:
  - Outdoor-to-outdoor
  - Outdoor-to-indoor
  - Indoor
  - Portable (nomadic users)
  - Mobile (vehicular users)

Applicative scenario (5)

- Supported applications:
  - Web browsing
  - FTP
  - E-MAIL
  - WAP (Wireless Application Protocol)
  - VoIP (Voice over Internet Protocol)
  - Video telephony – video conference
  - Audio streaming
  - File-sharing
  - Gaming …

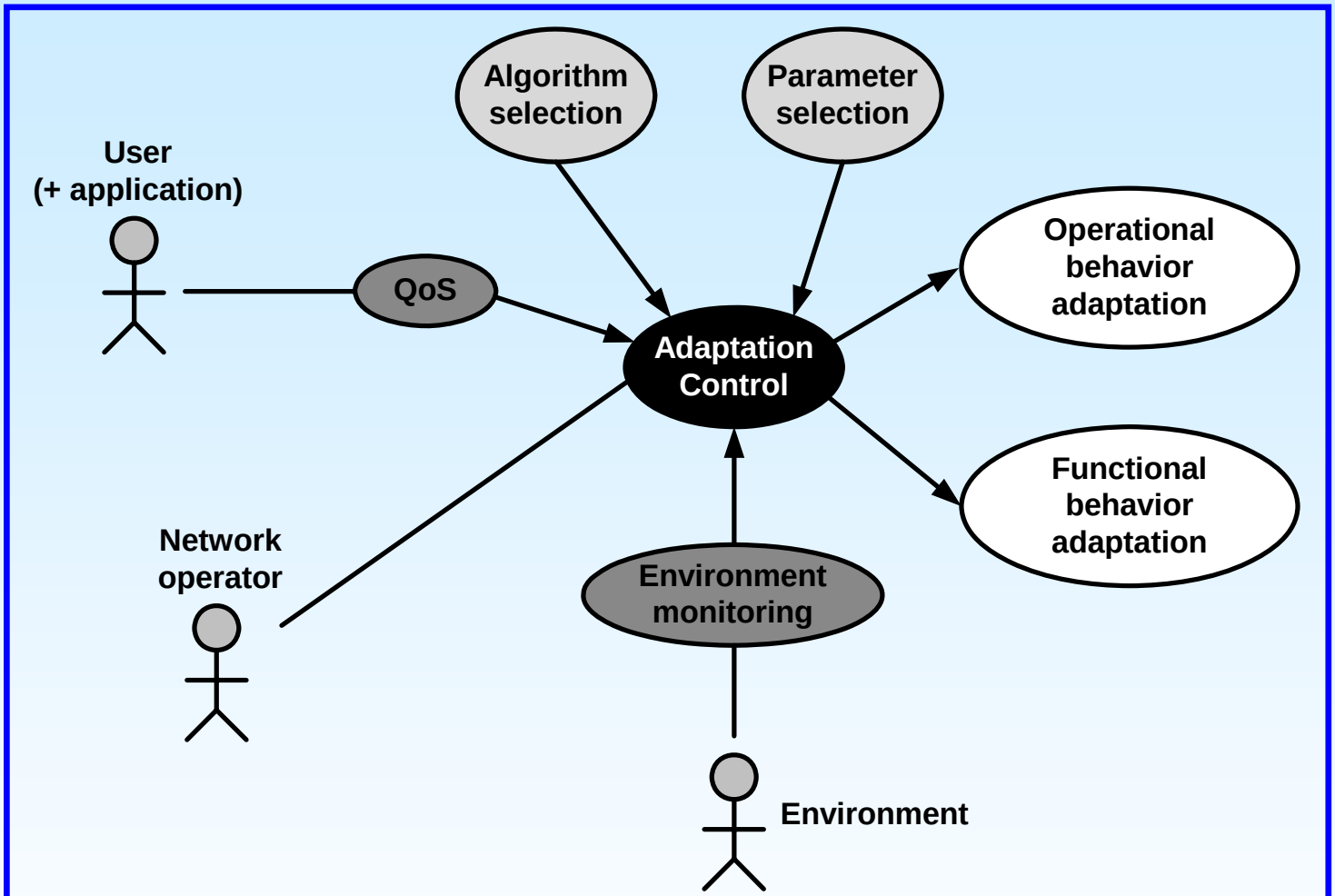
Self-adaptivity in the applicative scenario (1)

- Emphasis is given on the self-adaptation of the physical layer (digital modem) of the wireless system.
- The targeted single multi-purpose system has to be based on a self-adaptive (in terms of operational and functional behaviour) digital modem.
- The physical layer has to be capable to adapt its operational behaviour by adjusting its own parameters in order to improve its overall performance. The adaptation process requires that the system knows its present operative conditions, and, on the basis of this knowledge, it modifies its own parameters.
- The choice of when adjusting the parameters of the system depends on the achieved performance and since the system performance is related to the environment, the adaptivity of the system mainly depends on the channel conditions.

Self-adaptivity in the applicative scenario (2)

- The physical layer has to be capable to adapt its functional behaviour (reconfigurable) by rearranging its blocks and the interactions among them to support different functionalities.
- Certain tasks of the system allow different algorithmic implementations with different trade-offs between algorithmic performance and computational complexity.
- The reason of modifying the functionalities is that the system has to respond to the desired requirements of several services with different needs in terms of capacity, time constraints, coverage etc. (higher layers services' demands).

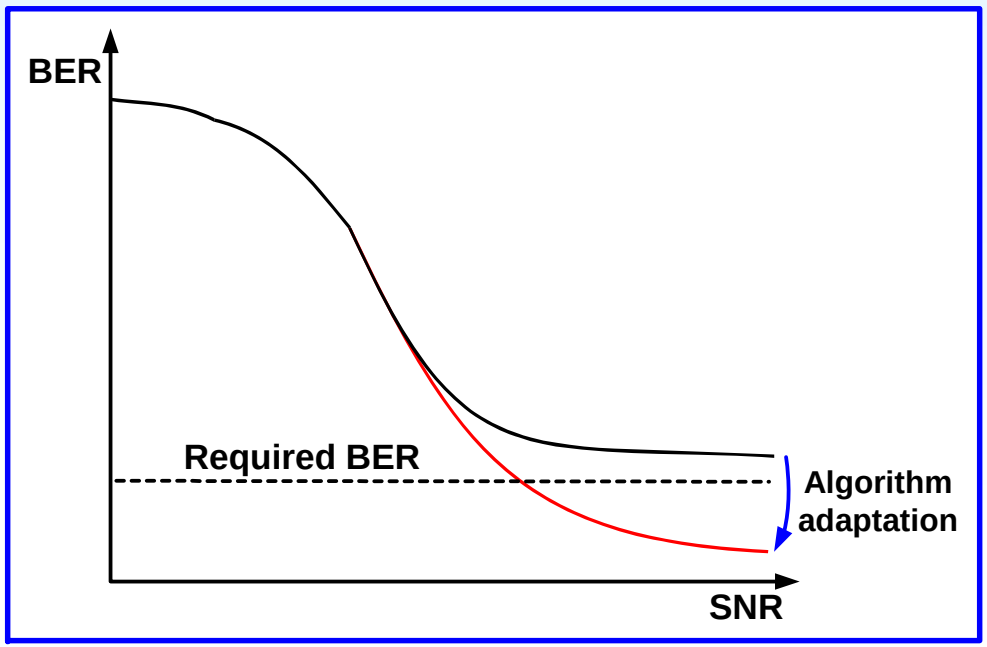
Self-adaptivity in the applicative scenario (3)



Actor	Role
User (+ application)	Defines the required Quality of Service (QoS).
Environment	Influences the received QoS via changed channel conditions (propagation conditions, signal strength, motion).
Network operator	Influences the received QoS via changing the network capacity.

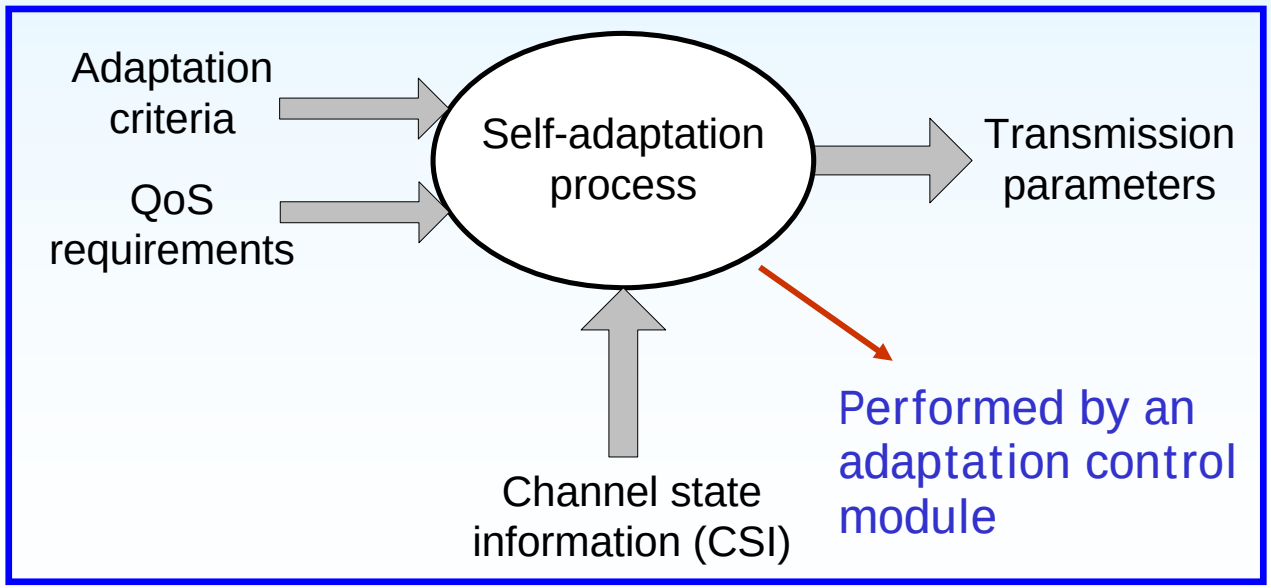
Self-adaptivity in the applicative scenario (4)

- For instance, self-adapted wireless terminals will have the capability to adapt the physical layer functionality to changes of the environment that impact the signal quality of the wireless transmission e.g. changing network capacity, mobile vs. stationary environment.
- A self-adaptive physical layer will be able to provide a user or an application with a predefined QoS level.
- This adaptation will influence many parts of the physical layer.



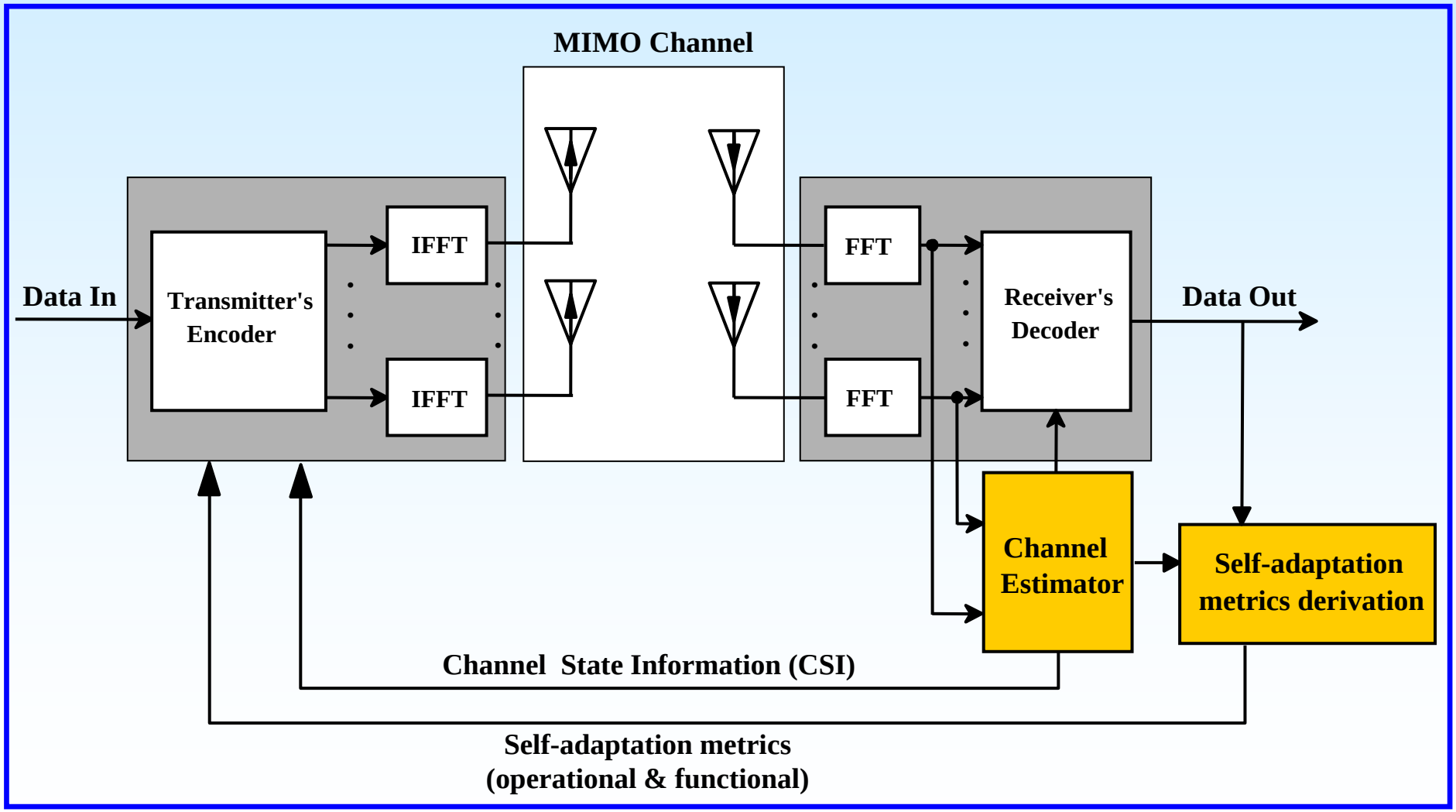
Basic self-adaptivity requirements (1)

- The parameters and the configuration of a wireless terminal have to be adaptive according to the environmental conditions, as well as to the user/application and network operator requirements (QoS).
- These requirements manifest themselves via a number of quantified attributes (requested bandwidth, bit-rate, BER etc.).
- The transmission parameters (modulation type/size, code rate, radiated power, used number of subcarriers etc.) are chosen to provide the requested QoS, as well as to satisfy other adaptation criteria (throughput, power etc.).



Basic self-adaptivity requirements (2)

- Regarding the influence of the channel conditions on the received QoS, self-adaptivity can be implemented in duplex communication systems, in which the CSI along with other adaptation metrics (criteria) are provided by a feedback channel.



Basic self-adaptivity requirements (3)

- Fundamental actions for self-adaptivity implementation:
  - Estimation of the channel state and, as a by-product, of the SNR at the receiver. CSI can be further processed at the receiver side in order to compute the values of the self-adaptive parameters of the transmitter, as well as other self-adaptation criteria. Such values are exploited by the transmitter when sending the next data frame.
  - Transmission of self-adaptation parameters.
  - Selection of self-adaptation algorithms in order to choose the transmission mode. This feature has to be taken into account carefully as all the related processes must be carried out before starting the transmission of a new frame.

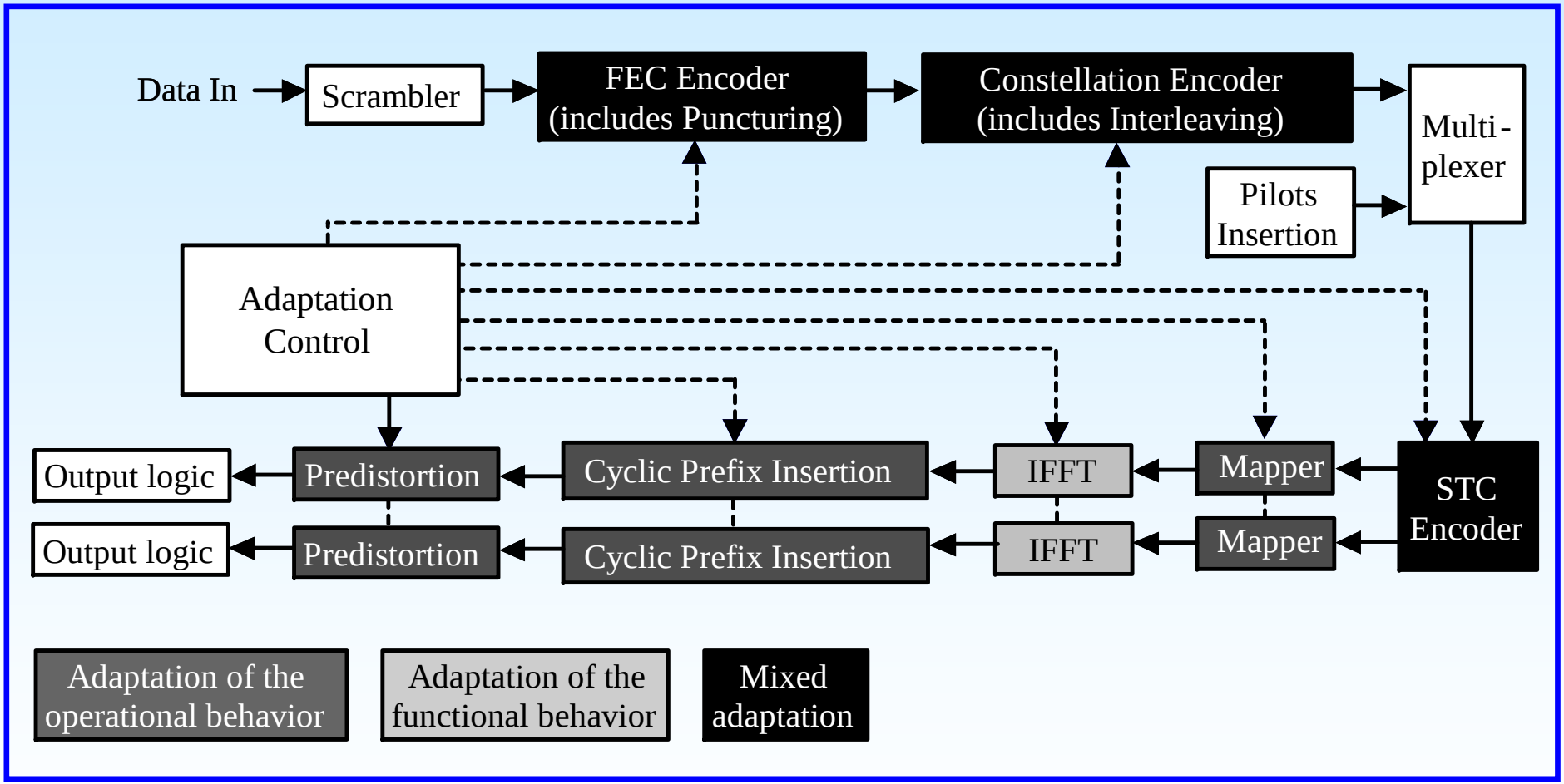
Basic self-adaptivity requirements (4)

- Each wireless terminal must have two properties:
  - Capable to adjust parameters at the same time with execution.
  - Dynamic partially reconfigurable.
- It is important to point out that the system has to be designed in a way to accommodate the temporary removal of reconfigurable blocks by using alternative datapaths bypassing the blocks that change, whereby data flowing through during reconfiguration time are treated as erroneous, since appropriate transformations (e.g. FEC encoding at the transmitter's side) have not been applied to them.
- In other words, the algorithmic blocks processing data must enter a state whereby it does not try to read or feed data to the block being replaced, thus avoiding processing of erroneous data or data processing that is cannot fulfil the system requirements.
- Reconfigurability can be seen as an enhanced feature compared to the adaptation of the operational behavior. The most relevant reason to trigger a reconfiguration, is the adaptation of the operation behavior (adjusting operational parameters) to be unable to respond to the desired requirements.

Summary of self-adaptivity requirements

- Capability to adjust parameters at the same time with execution.
- Dynamic (run-time) reconfiguration capability.
- Partial reconfiguration capability.
- QoS-related measurements capture (provision of monitoring functionality).
- Provision of management functionality for predefined adaptation metrics.
- Support adaptation and configuration changes initiated from upper communication layers.
- Capability to react to events and perform adaptation and configuration changes, autonomously, without affecting the integrity of the current overall configuration.
- Support adaptation criteria such as minimization of a wireless terminal power consumption and radiated power and maximization of throughput.

Adaptation at the transmitter of the modem (1)



Adaptation at the transmitter of the modem (2)

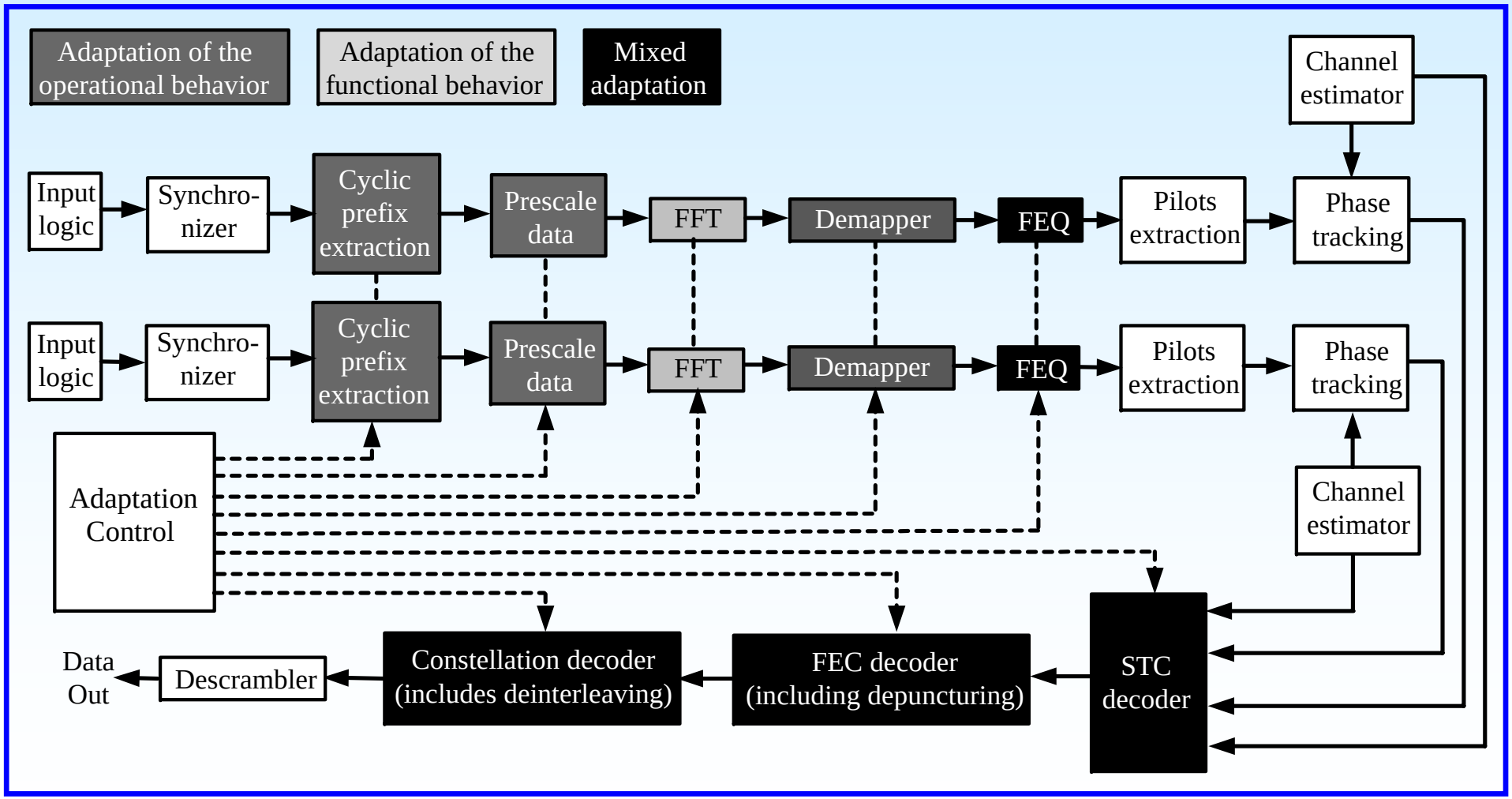
- Adaptation of the operational behaviour:
  - Predistortion: implements the power loading adaptivity (scales the signal symbols according to the CSI gathered from the receiver). Adaptive parameter is the power assigned to each subcarrier.
  - Cyclic prefix insertion: adaptive parameter is the length of the cyclic prefix (its modification according to the CSI optimizes the bandwidth efficiency of the system).
  - Mapper: adaptive parameter is the number of subcarriers per symbol.
- Adaptation of the functional behaviour:
  - IFFT: by implementing IFFT with different size (number of points) we can modify the coverage of our system.

Adaptation at the transmitter of the modem (3)

- Mixed self-adaptive blocks:
  - Adaptation of the functional behaviour (reconfiguration) concerns switching from one configuration to another, while adaptation of the operational behaviour regards the adjustment of the parameters in each configuration.
  - FEC encoder:
    - ✓ Operational behavior: adjust puncturing rule, coding rate.
    - ✓ Functional behavior: convolutional coding, turbo coding etc.
  - STC encoder:
    - ✓ Operational behavior: adjust parameters determining the way for the serial-to-parallel conversion.
    - ✓ Functional behavior: different configurations regard the use of Space-Time-Frequency coding, STF turbo coding, STF LDPC-based coding etc.
  - Constellation encoder:
    - ✓ Operational behavior: adjust size and type (mode) of constellation employed for each subcarrier.
    - ✓ Functional behavior: variable-rate, fixed-rate algorithms for selection of subcarriers constellation.

Adaptation at the receiver of the modem (1)

- Any choice made for the transmitter must be communicated to the receiver, so that the receiver to exploit the related information in order to adapt the operational and/or functional behavior of its algorithmic blocks, so that data detection can be properly carried out.



Adaptation at the receiver of the modem (2)

- Adaptation of the operational behaviour could take place at algorithmic blocks such as: cyclic prefix extraction, prescale data, and demapper.
- Adaptation of the functional behaviour could take place at the FFT block and it is related to the number of points of the transformation.
- Mixed-type adaptation takes place at blocks such as: constellation decoder, FEC decoder and STC decoder. The adaptation at these blocks depends on the parameters and algorithms used for the data transmission.
- Operational adaptation at the equalizer (FEQ) can be achieved by choosing the criterion used for the equalizer coefficients updating: minimization of the peak distortion (zero-forcing ZF method) or minimization of the mean-square error (LMS method).
- The adaptation of the functional behavior in FEQ refers to the implementation way of the equalization (linear or decision-feedback).