5G NR and 6G Experimental Platform

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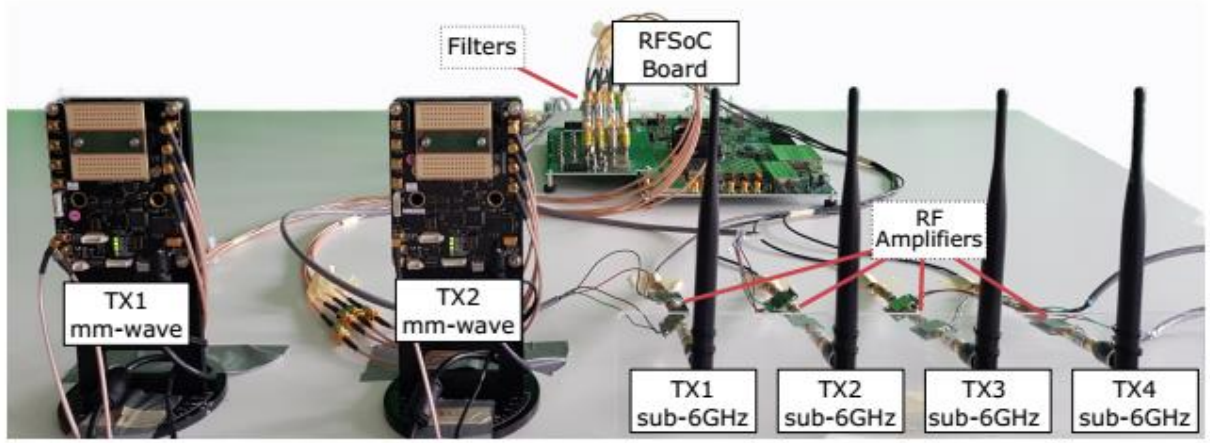
Developing the Science of Networks

One Platform for mmWave and sub-6 GHz Research

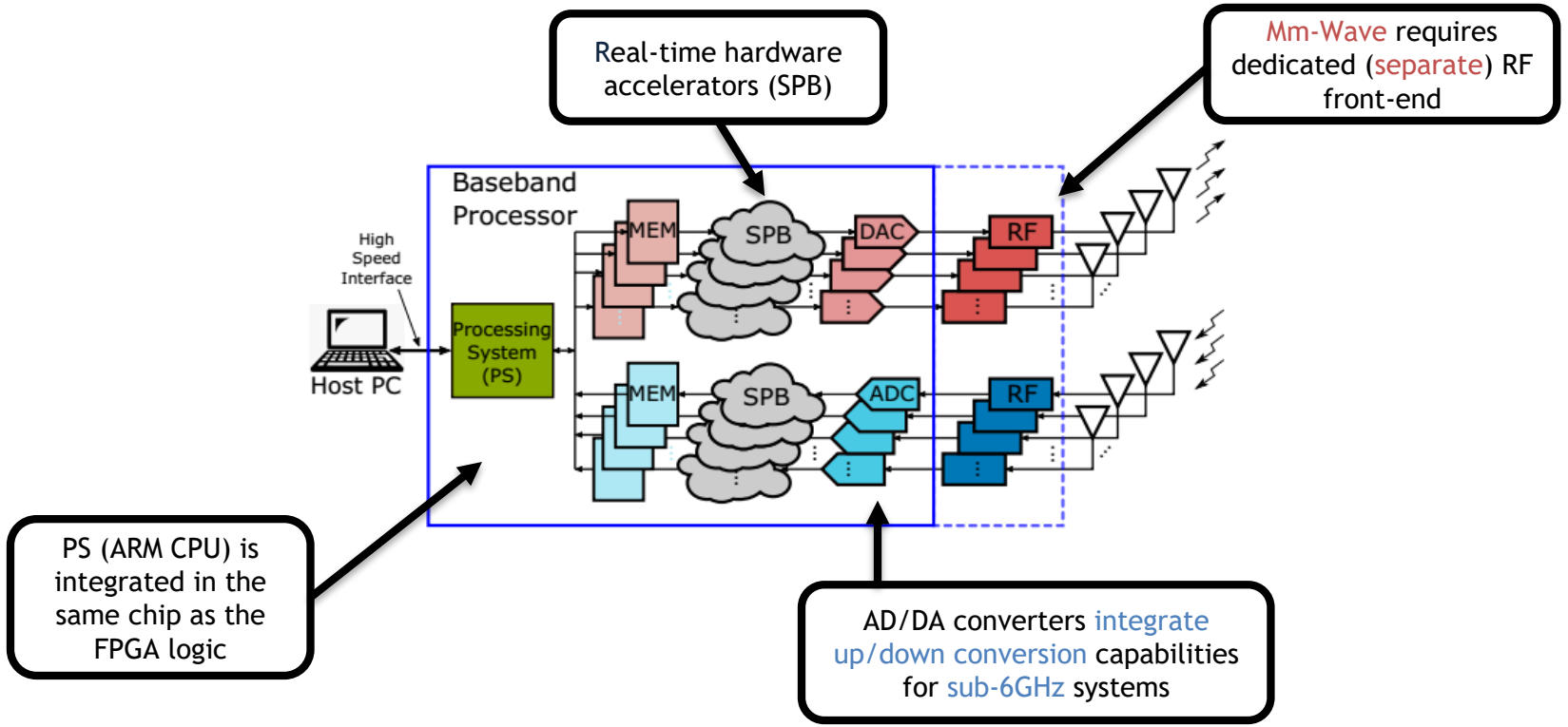
- Many different high-performance wireless systems wrt. frequency spectrum, MIMO-order, bandwidth → complex prototyping
- Open-source system based on Xilinx RFSoC board
  - Configurable data-paths for flexible bandwidth, MIMO-order
  - Memory-based design (to speed up prototyping), with hardware accelerators to support real-time functionality
  - Supports sub-6 GHz directly and mmWave via up-/down-converters (28 GHz, 60GHz)
    - Even mixed configurations (mmWave + sub-6 GHz)
    - Up to 2 GHz of bandwidth per channel
    - Up to 8x8 MIMO at IF, 4x4 MIMO at baseband



J. O. Lacruz et al., "A real-time experimentation platform for sub-6 GHz and millimeter-wave MIMO systems", *ACM MobiSys*, 2021

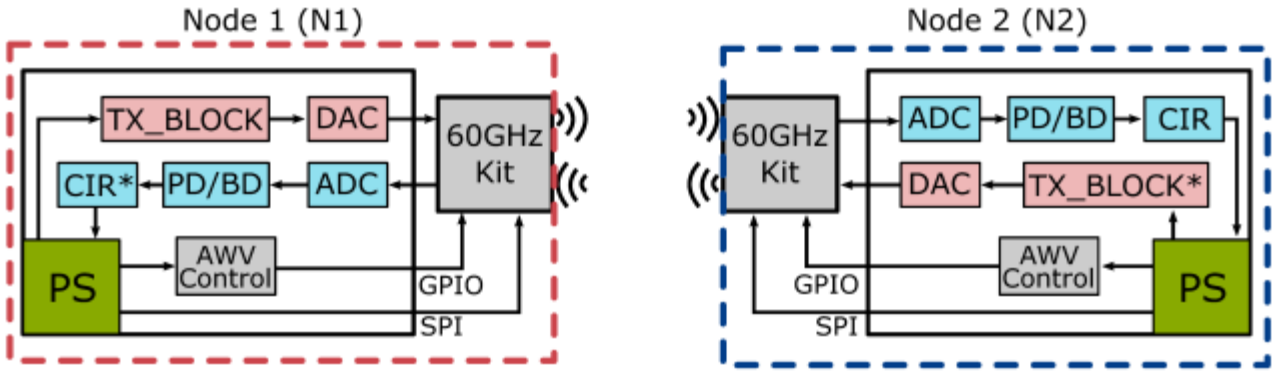
MIMORPH platform

- Memory-based design
  - Stream samples to/from on-board DRAM, offloading via Ethernet
  - Easy experimentation → send & capture frames and process in software (e.g., Matlab)
  - HW accelerators on the FPGA for time-critical functions



MIMORPH platform

- Closed-loop operation
  - First of its kind for mmWave experimentation
  - Several hardware accelerators to enable functionality
    - Packet detection / synchronization (currently for IEEE 802.11ay)
    - 4x4 MIMO channel estimation and beam tracking → ~100us Tx-Rx latency of the control loop
    - Nanosecond-level antenna reconfiguration → using GPIO / SPI functionality on the RFSoC and RF front-ends



Extensions towards a *real-time* 5G/6G platform

- Alternatives: OpenAirInterface, srsRAN, Aerial
  - Standard compliant, but complex, limited scalability → *very* difficult/impossible to support high bandwidths and high MIMO orders
- Our platform: less functionality, not compatible with smartphones, but higher performance, better modularity
- Simple FR1/FR2 implementation based on the MIMORPH platform
  - Detect synchronization signals (SSB)→ PSS, SSS, PBCH
  - CFO compensation
  - Acquisition of timing information
  - Channel estimation
  - 5G standard-compliant timing and frame format
  - Full OFDM symbol decoding: fixed sub-carrier spacing, for specific MCS, LDPC rate, BW (i.e., FFT length)

Extensions towards a *real-time* 5G/6G platform

Future:

- Real-time transmitter
- Support of initial access procedure
- Multiple spatial streams
- Standard compliant integration with upper layers (MAC, RLC) → support functional splits according to 3GPP
  - Considering options 6 (HIGH-PHY) and 7-2 (LOW-PHY)
  - High-performance 10G/100G Ethernet implementation
- Further bandwidth configurations, sub-carrier spacing, MCS, HARQ, …