Intermediate Transceiver and Frame Structure Concepts and Results

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What is 5GNOW?

5GNOW (5th Generation Non-Orthogonal Waveforms for Asynchronous Signalling) is an European collaborative research project supported by the European Commission within FP7 ICT Call 8.

Who is in the consortium?

- Fraunhofer HHI (coordinator), Germany, Dr. Gerhard Wunder
- Alcatel Lucent (technical coord.), Germany, Thorsten Wild
- Technische Universität Dresden, Germany, Prof. Gerhard Fettweis
- CEA-LETI, France, Dr. Dimitri Ktenas
- IS-Wireless, Poland, Dr. Slawomir Pietrzyk
- National Instruments, Hungary, Dr. Bertalan Eged

www.5gnow.eu, LinkedIn group

Vision:

- 5GNOW is the physical layer evolution of mobile communication network technology such as LTE-Advanced towards emerging application challenges.
(1) 5GNOW Status

(2) Sporadic Traffic Support

(3) Compressive Random Access

(4) Conclusions
Milestone I: Initial system concept.  (√)

Milestone II: Waveform selection and basic MAC features.  (√)

Altogether 8 deliverables submitted.  (√)
5GNOW Status/Topics

- **D2.1 (public)**: 5G application requirements/scenarios
  - Scenarios: Super high-rate /CoMP, Sporadic traffic / IOT, Fragmented spectrum / Digital Agenda, Very low delay / Tactile Internet

- **D3.2 (confidential)**: Waveform design

- **D4.1 (public, IR4.2)**: Complementary MAC design/Robustness framework

**Main result:** Unified Frame Structure concept + Waveforms + 5G Random Access
Sporadic Traffic Support
Sporadic traffic: device wakes up once in a while, sends a few packets and goes back to sleep

- IoT machine-type communications (3GPP: >30000 devices/cell)
- Smartphones' short messages
- TI fast access: <1ms latency

Requires fast asynchronous access with control signaling and devices’s payload “in one shot”

4G does not scale: Bulky access procedure (scheduled access only); large overhead (up to control/data ratio up to 2000%) and high latency (>10ms)
Sporadic Traffic

- Illustration of 4G / 5G-PRACH

Elements of 5G random access:
“Fast” sporadic traffic support in physical layer random access channel (PRACH)

Scheduled Access Data

Payload

PRACH

Contention Based Access

Time

Frequency
Sporadic Traffic

- Many users can potentially access the resource; resource is not designed to accommodate all users.
- Data and control in the same resource ("one shot transmission"); control cannot be separated from data.
- Example dimensions: 100k x >20kBit/s x 100us delay spread.

LTE-A 4G: B=20 MHz, T=1ms subframe yields 20000 dimensions! Impossible to reserve data and control resources for any number of devices!

- Exploit sparsity of
  - user activity
  - message sizes
  - and channel profiles is expected.

Mixture of overload situation under sparsity and compressive measurements: : Compressive Random Access
Compressive Random Access
- Unified frame structure
- Traffic classes require common control signalling
- Compressive measurements in dedicated slot $\mathcal{B}$
- Underlay signaling
- Goal: 5G PRACH illuminates the full bandwidth of all user’s channels

Theorem:

\[ R(\alpha) \geq \log(1 + \text{SNR} \cdot (1 - \alpha)) - \log \left( 1 + \frac{M}{N} \cdot c_2 (\delta_{2k})^2 \left( \text{SNR} \cdot \frac{1 - \alpha}{\alpha} + \frac{1}{\alpha} \right) \right) \]

Moreover, if the “partial circulant” measurement matrix \( P_B \cdot \text{circ}(\xi) \) with \( B \) chosen uniformly at random with cardinality \( M = |B| \) such that:

\[ M \geq c_1 \delta^{-2} \min(K \log^6 N, K^2 \log N) \]

has RIP with probability \( \geq 1 - c_2 N^{-1} \) and \( \delta_{2k} \leq \delta \) (\( \log^5 \) for a fixed probability).

5GNOW RACH Example:

- Various numbers of users/devices
  - Up to 10 users/devices out of 10 / 50 identified within 1ms
- 20 dB SNR
- Channel estimation, channel equalization and decoding in 1ms shot in parallel
- $\alpha$ is the fraction of the control signalling (preamble) power (consequently $1 - \alpha$ is the power fraction of the data part)
Simulations Results

- Probability of missed detections vs. probability of false alarm
- LTE requirements: $P_{FD} \leq 10^{-3}; P_{MD} \leq 10^{-2}$
Dissemination & Conclusions & Outlook
Dissemination

Window of opportunity 2014/2015 for launching a study item for non-orthogonal wave forms and transmission schemes

- Initiating new standardisation process towards 5th Generation mobile networks
- 5GNOW explicitly named by several EU officials to have fostered 5GPPP
Conclusions / Next Steps

■ 5GNOW Main Result: Different traffic types can be accommodated in Unified Frame Structure concept by robust waveform design

■ Efficient Compressive Random Access scheme:
  ■ Joint transmission of data and control signalling possible
  ■ Compressive measurements in dedicated channel are sufficient

■ Initial performance results appear highly promising, on-going investigations and even future projects planned

■ Next steps: system-level simulations of massive MTC scenarios with new RACH concepts
Thank you for your attention!

www.5gnow.eu

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