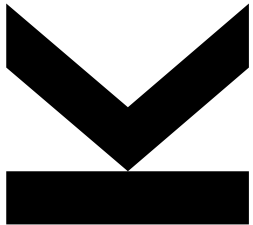# Integration of Molecular Communications into Future Generation Wireless Networks

Werner Haselmayr, A.Springer, G. Fischer, C. Alexiou, H. Boch, P.A. Hoeher, F. Dressler, and R. Schober
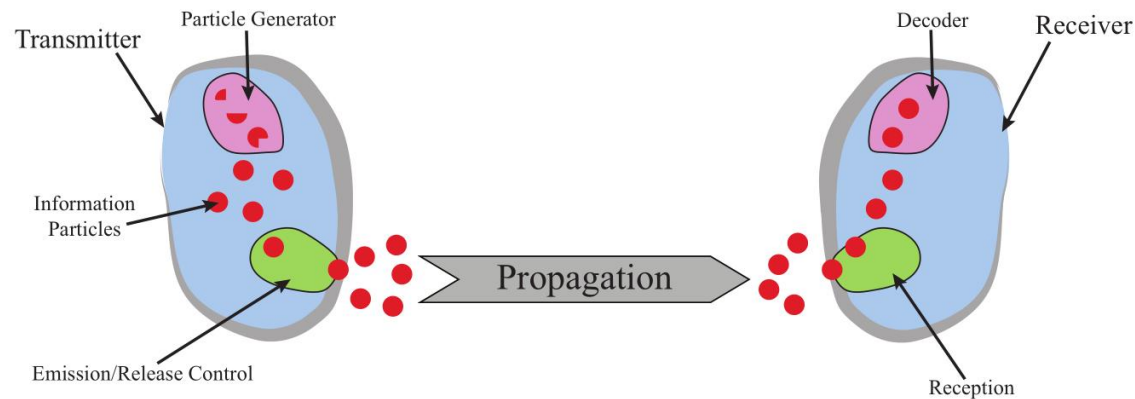
OUTLINE

¢ Why Molecular Communications (MC)

¢ Macro-Scale MC

¢ Micro-Scale MC

¢ Integration into Future Generation Wireless Networks

¢ Summary

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WHY MOLECULAR COMMUNICATIONS (MC)

₵ Communication where the use of EM waves becomes challenging
- £ Human body
- £ Pipe networks

₵ Information transmission through molecules (inspired by nature)

₵ Bio-compatible and high energy efficiency

₵ Macro- (>mm) and micro-scale (<mm)

Source: Y. Murin et al., "Optimal Detection for Diffusion-Based Molecular Timing Channels," *IEEE Trans. Mol. Biol. Multi-Scale Commun.*, 2019, submitted for publication.

MC COMPONENTS

¢ IEEE standardization efforts (IEEE 1906.1)

¢ TX and RX could be biological (synthetic cells) or electronic devices (spray, sensor)

¢ Transmitter
  £ Modulation: Concentration, type, or release time

¢ Propagation channels
  £ Diffusion, flow-assisted, or walk

¢ Receiver
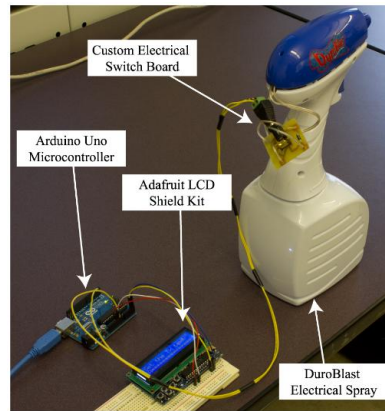 £ Absorption, observation
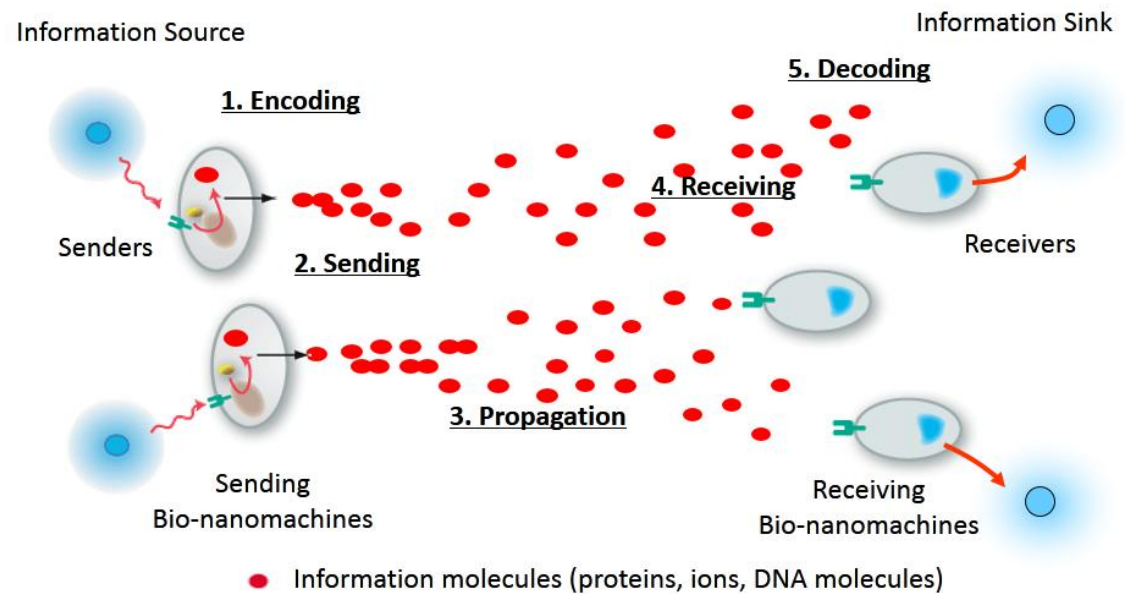
Source: T. Suda and T. Nakano, "Molecular Communication: A Personal Perspective," *IEEE Trans. Nanobiosci.*, vol. 17, no. 4, pp. 424-432, Oct. 2018.
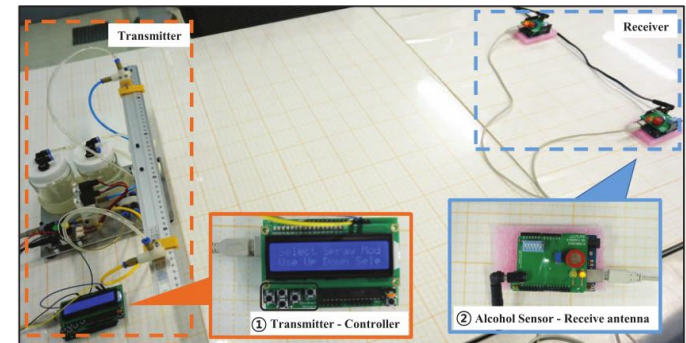
MACRO-SCALE MC

- Range: mm – m
- Practical realization in near-future
- Enables communication in complex and harsh (industrial) environments
  - Tunnels or mines
  - Pipe networks
- Possible application: Smart infrastructure monitoring
- Experimental platforms available
  - Air-based
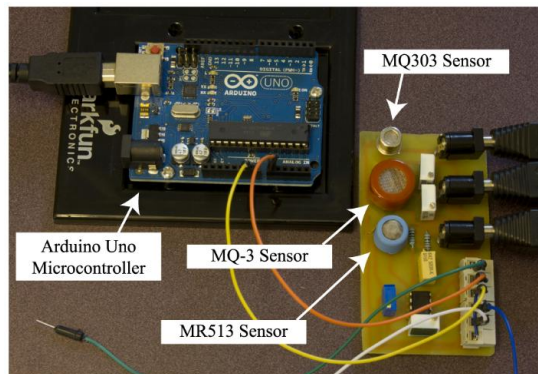 - Fluid-based

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MACRO-SCALE MC – AIR-BASED DEMONSTRATORS

- First MC testbed
- TX/RX: Spray, sensor
- Alcohol molecules
- Ventilator

Source: N. Farsad et al., "Tabletop Molecular Communication: Text Message through Chemical Signals," PLOS ONE, Vol. 8, Dec. 2013
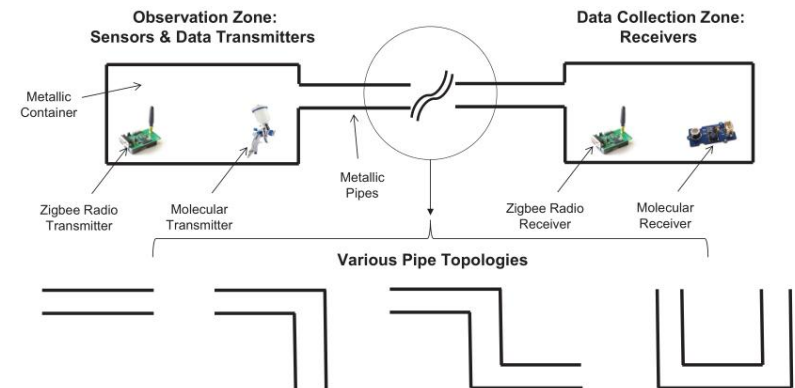
- Multiple sprays and sensors

Source: B.H. Koo et al., "Molecular MIMO: From Theory to Prototype," *IEEE J. Sel. Areas Commun.*, vol. 34, pp. 600-614, Mar. 2016.
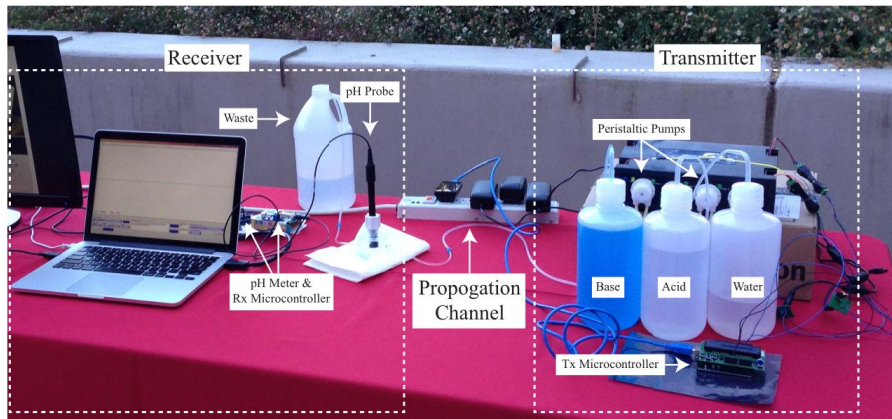
- Confined environment

Source: S. Qiu et al., "A Molecular Communication Link for Monitoring in Confined Environments," in *Proc. Int. Conf. Communications*, pp. 718-723, Jun. 2014.
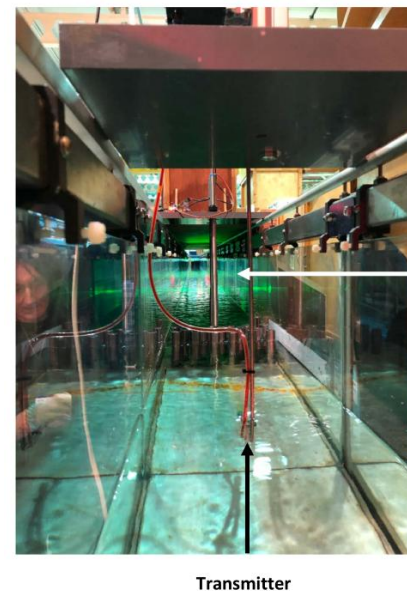
MACRO-SCALE MC – FLUID-BASED DEMONSTRATORS

₵ TX/RX: Peristaltic pumps/pH sensors

₵ Multi-chemical platform (acid and base)

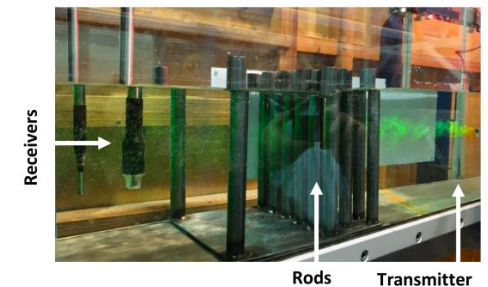
Source: N. Farsad et al., "A Novel Experimental Platform for In-Vessel Multi-Chemical Molecular Communications," in Proc. Global Communications Conf., Dec. 2017, pp. 1-6.
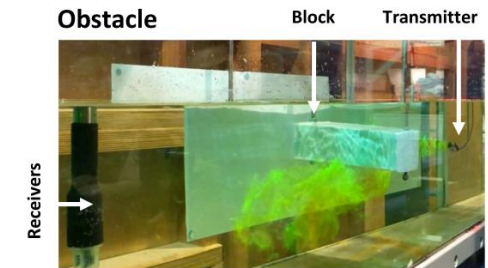
₵ Impact of different obstacles

Source: Iresha Atthanayake et al., "Experimental molecular communications in obstacle rich fluids," in *Proc. Int. Conf. Nanoscale Computing and Communication*, Sept. 2018, pp. 1-2.

MC FOR INDUSTRIAL APPLICATIONS (MAMOKO)

- ¢ Recently launched project
    - £ 5 German universities
    - £ 08/2019 – 10/2021 (3 years)
    - £ €3.26 million
- ¢ **Goal:** Applicability of macro-scale MC for industrial applications
- ¢ Theoretical design and practical implementation of air- and fluid-based macro-scale MC system
- ¢ Example: Experimental testbed based on magnetic nanoparticles
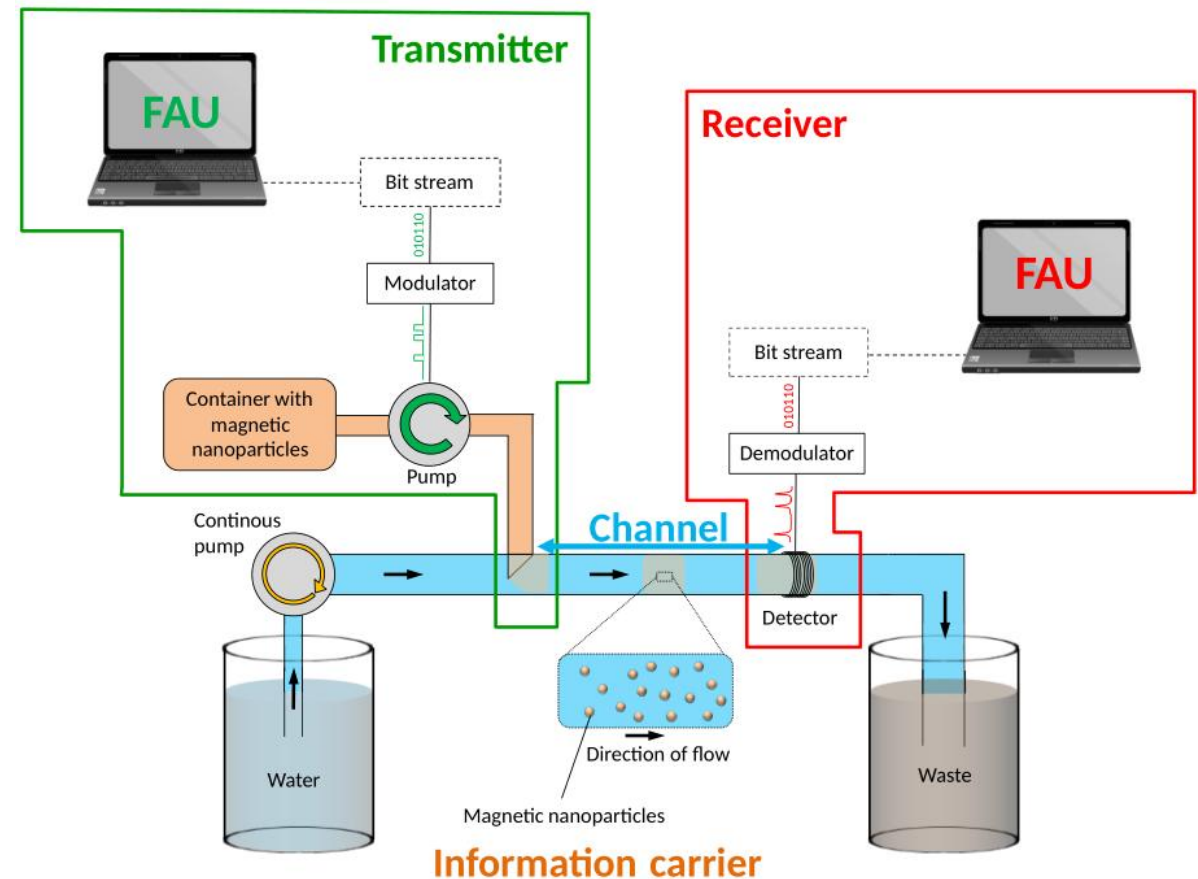
Source: MAMOKO project proposal.

MICRO-SCALE MC

- ₵ Range: nm – mm

- ₵ Still in its infancy

- ₵ Envisioned applications
  - £ Internet of Bio-NanoThings (IoBNT)
  - £ Targeted (cooperative) drug delivery
  - £ Intra-body networks

- ₵ Mainly theoretical studies

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INTERNET OF BIO-NANOTHINGS (IoBNT)

¢ Advancement of IoT and IoNT

¢ Bio-Nanothings: Synthesized biological cells

¢ MC is well suited for communication in IoBNT

Source: I. F. Akyildiz et al., "The internet of Bio-Nano things," *IEEE Commun. Mag.*, vol. 53, no. 3, pp. 32–40, Mar. 2015.
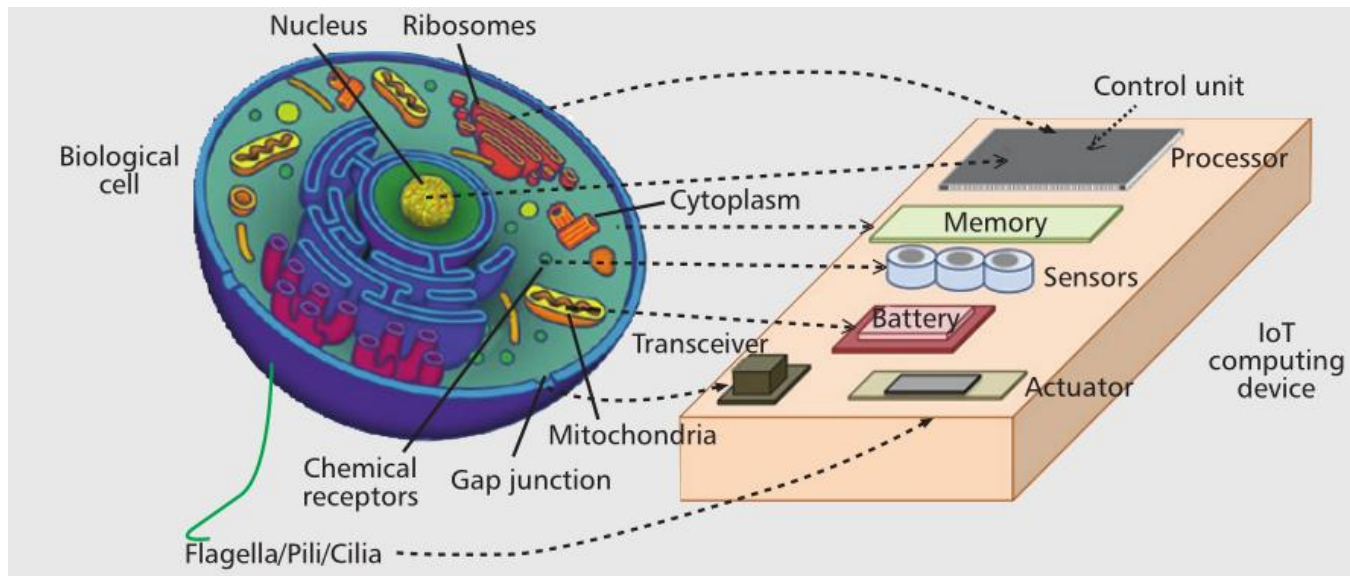
INTEGRATION INTO FUTURE WIRELESS NETWORKS

¢ Bio-cyber interface
  £ Molecular ⇔ EM
  £ Application dependent

¢ Security mechanisms
  £ Malicious attacks
  £ Classical and nature-inspired methods
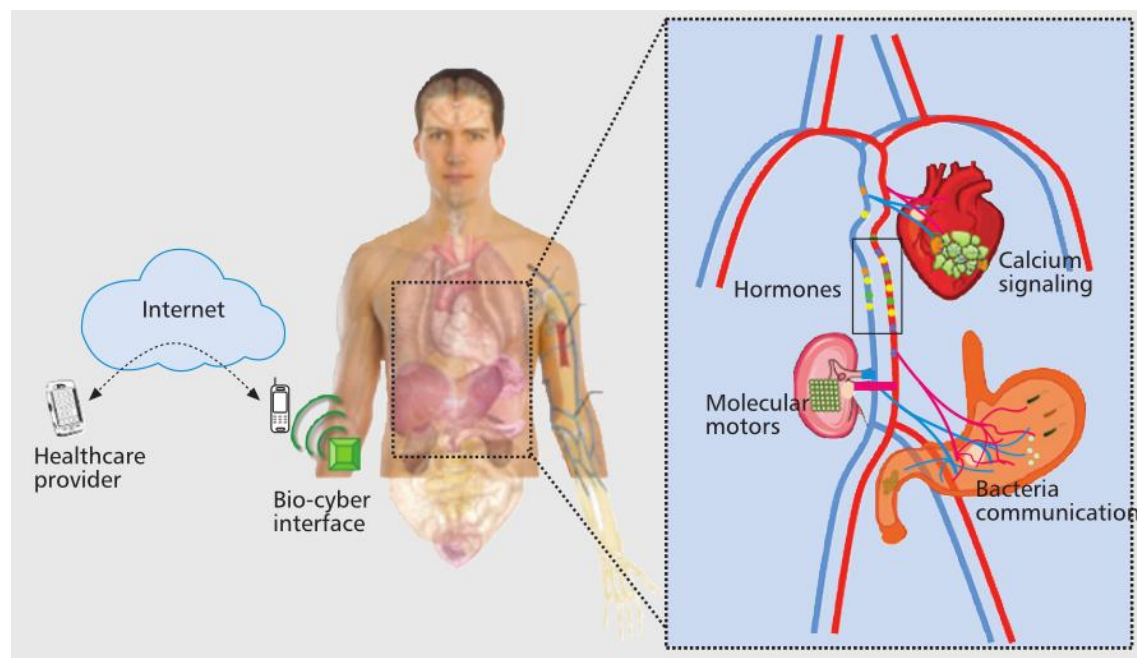
Source: I. F. Akyildiz et al., "The internet of Bio-Nano things," *IEEE Commun. Mag.*, vol. 53, no. 3, pp. 32–40, Mar. 2015.

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MC-RELATED CHALLENGES

¢ Physical layer techniques for micro- and macro-scale MC
  £ Channel estimation, detection, …

¢ Design of embedded devices with MC capabilities

¢ Development of bio-nanothings

¢ Development of application-oriented testbeds

¢ Standardization of a layered architecture for MC

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SUMMARY

- MC holds great promise in complex environments
- Micro-scale MC
  - Still in its infancy
  - Medical applications (e.g., intra-body networks)
- Macro-scale MC
  - Practical realization in near future
  - Smart infrastructure monitoring
- Main challenges
  - Bio-cyber interface
  - Security mechanisms

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WANT TO KNOW MORE ABOUT MC?

- ₵ 4th Workshop on MC
- ₵ 16-18 April 2019, Linz, Austria
- ₵ 3 keynotes, 2 tutorials, 4 technical sessions
- ₵ Web: https://molecularcommunications.eu/

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JOHANNES KEPLER
UNIVERSITY LINZ

Home | Program | Registration | Call for Papers | Organization | Accommodation | Contact

4th Workshop on Molecular Communications

16-18 April 2019
Linz, Austria

Description

The 4th Workshop on Molecular Communications is being held in Linz, Austria, on April, 16th-18th, 2019. Building on the success of the previous three workshops, this workshop will act as a hub of knowledge exchange of Molecular Communication Research in Europe with a focus on broadening the reach of the community into border disciplines. Disciplines we wish to attract include (but are not limited to):

- Synthetic Biology
- Systems Biology
- Pharmacology
- Inter/Intra Cellular Communication
- Chemical Networks
- Communication Engineering

The workshop will deliver three profile keynote speeches in multidisciplinary topics and incorporates two focused tutorials aimed at young researchers. Moreover, the workshop will run three technical sessions focusing on emerging hot topics and will host three panel sessions.

IMPORTANT DATES

Abstract submission
February 17th, 2019

Notification of acceptance
March 15th, 2019

Camera-ready Due
April 5th, 2019

Conference
April 16th-18th, 2019

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DRAFT

¢ MolCom (2 slides)
- £ Definition, Pros/cons (bio-compatible, low-energy, slow, ISI (!)), Application, Standardization
- £ Models for TX, Channel and RX
- £ Micro- and Macro-scale

¢ Macro-Scale (4 slides)
- £ Realization in near future
- £ Show demonstrators (Air-based (spray), fluid-based (acid/base, cell)
- £ Mamoko (1slide)

¢ Micro-Scale (Internet of BioNanothings) (2-3 slides)
- £ IoT -> IoNT -> IoBNT; explain idea; applications

¢ Research challenges

¢ Opportunities/Applications/Challenges for Integration of MC in 6G (2 slides)

¢ Summary (1 slide)

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