ESCAPADE:
Enhancing communication security by cross-layer physical and data-link (PDX) techniques

Application scenario 1

- Secure wireless networks without pre-shared secret keys

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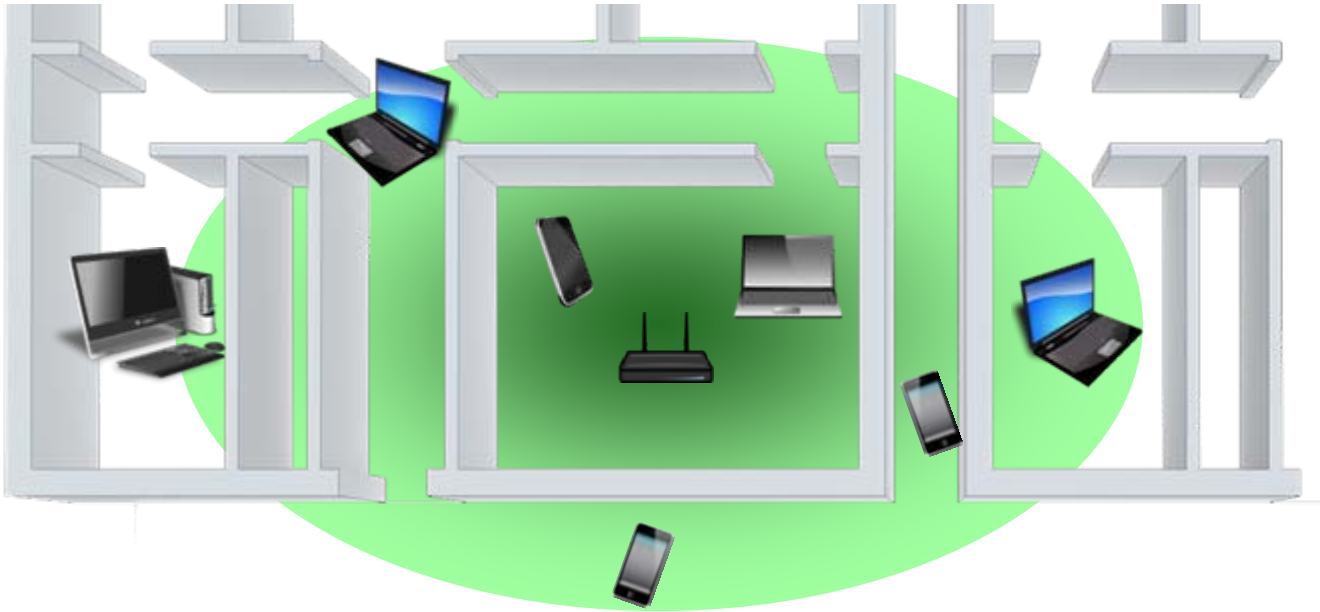

open network

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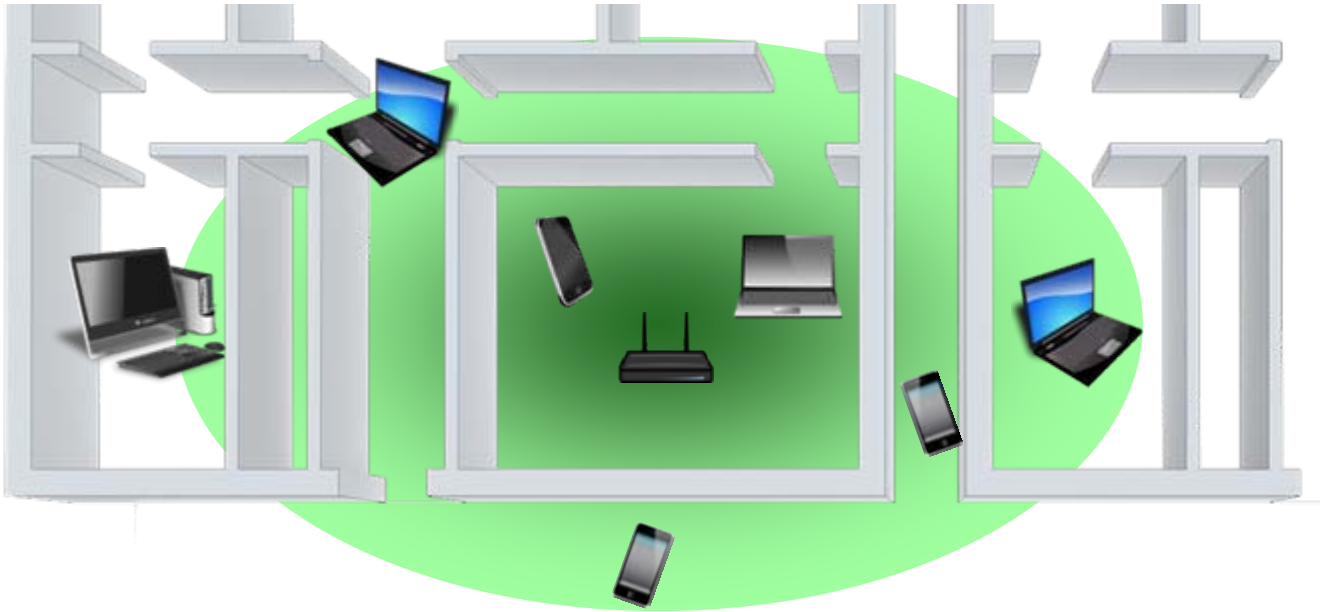

open network

need of a pre-shared key

(store, share, protect, renew…)

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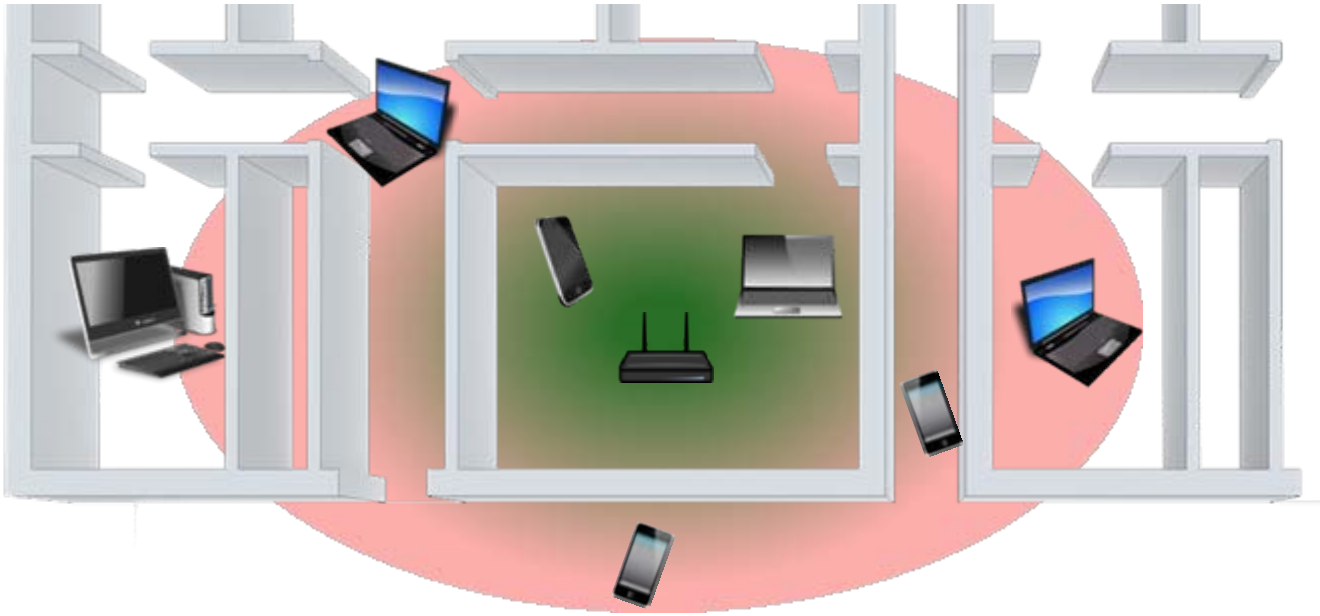

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PDX security

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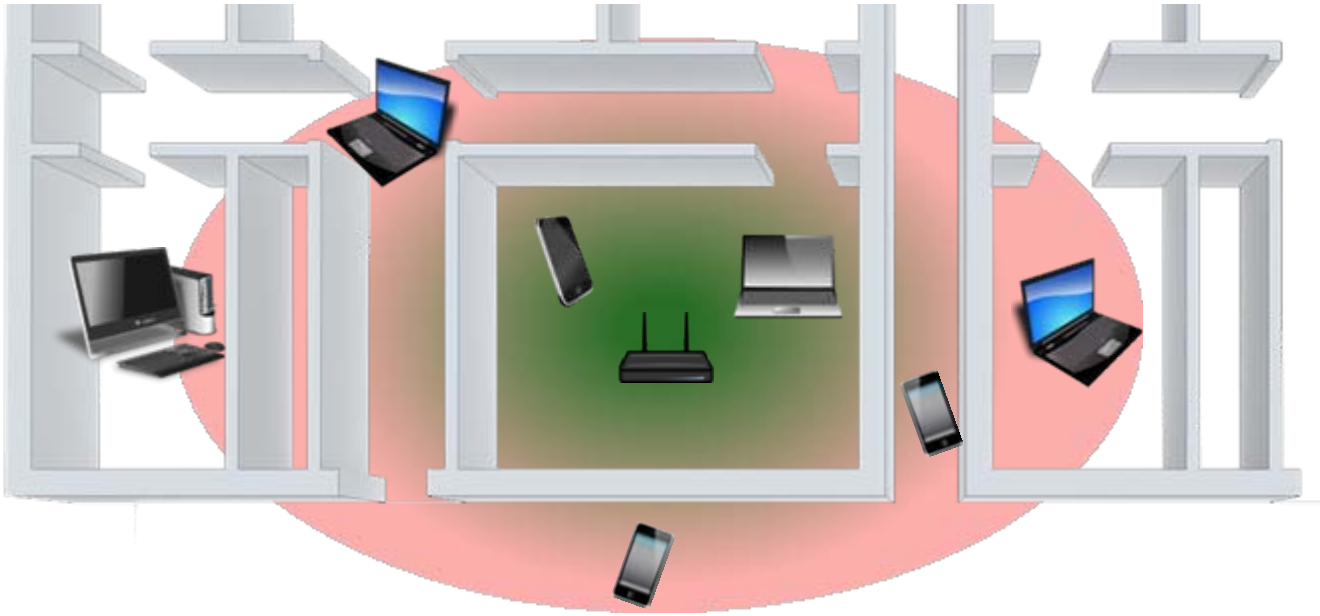
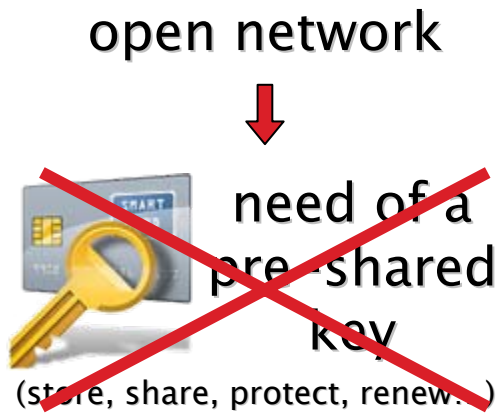
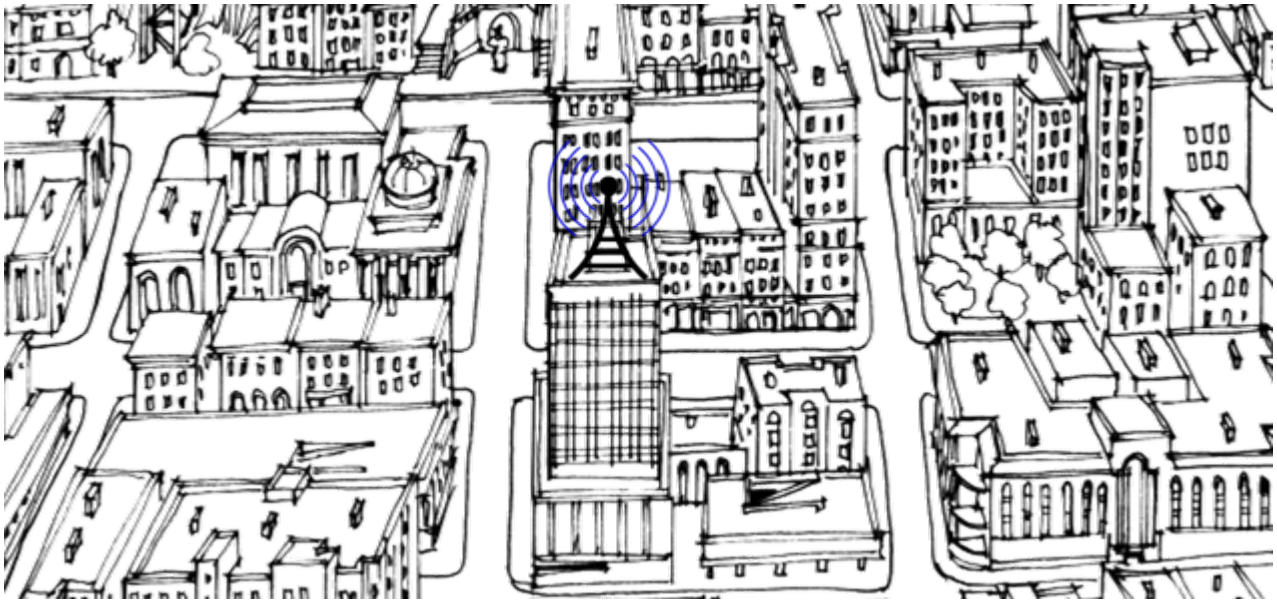




- Can be implemented in existing IEEE 802.11b/g/n networks
- Existing (free) network card drivers can be adapted
- Minimal hardware costs, mostly software development costs

Application scenario 2

- Broadcast transmission with confidential messages



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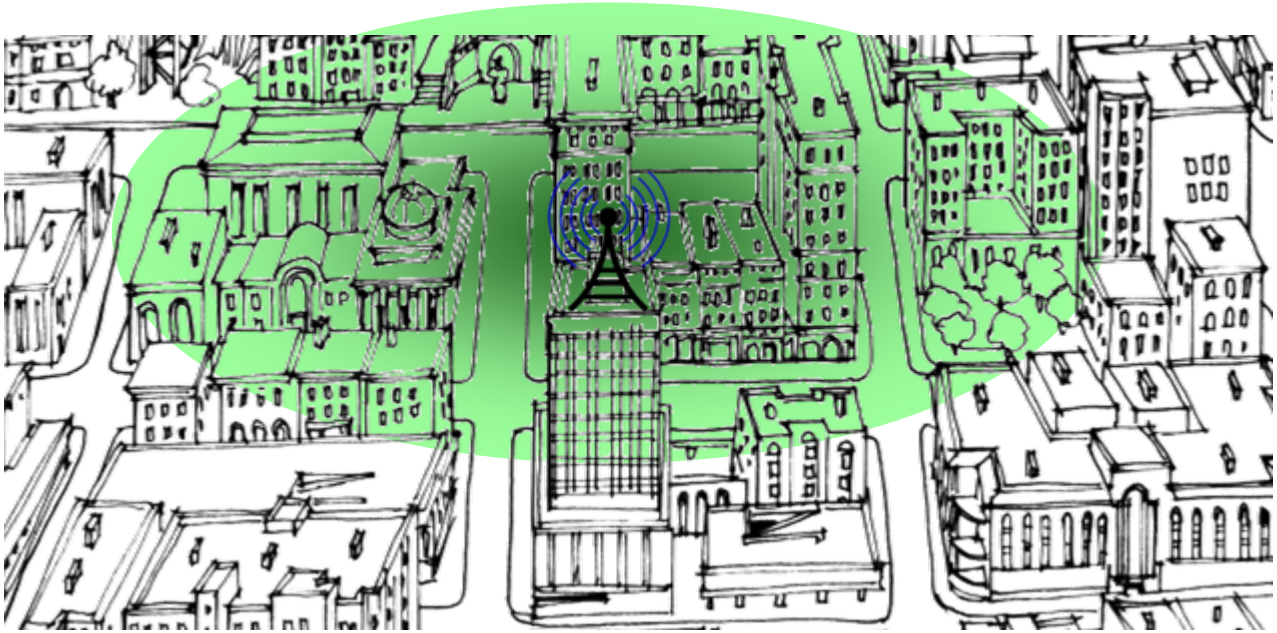

only free-to-air

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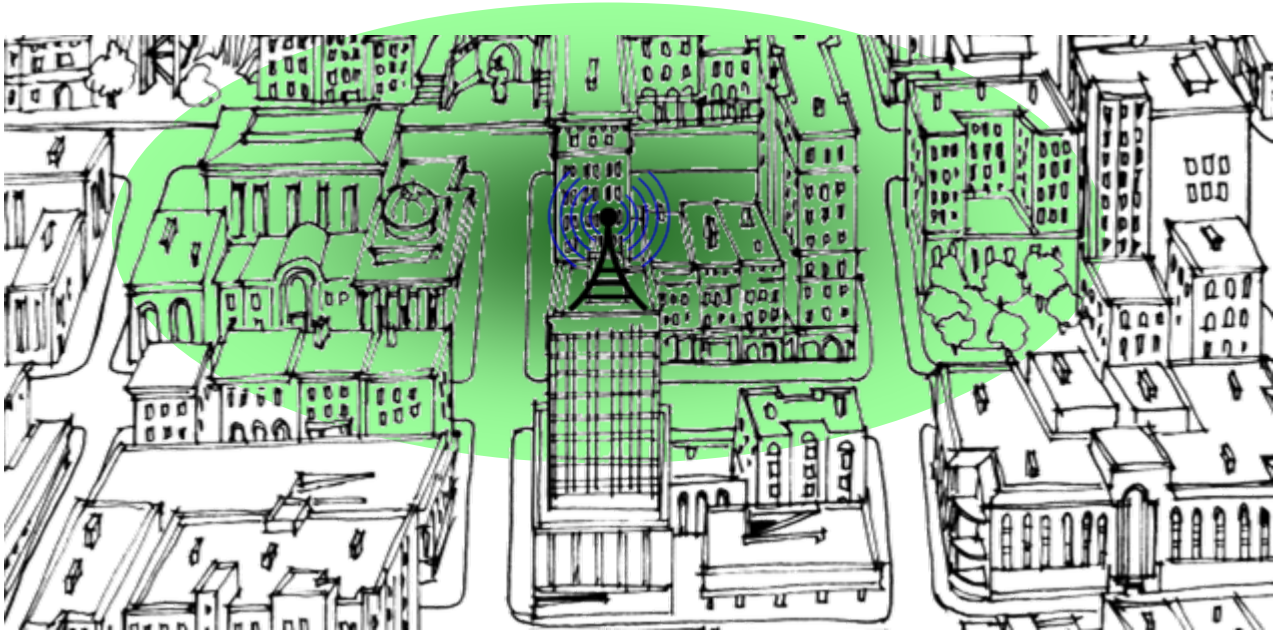

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keys
(smart cards)
for subscribers

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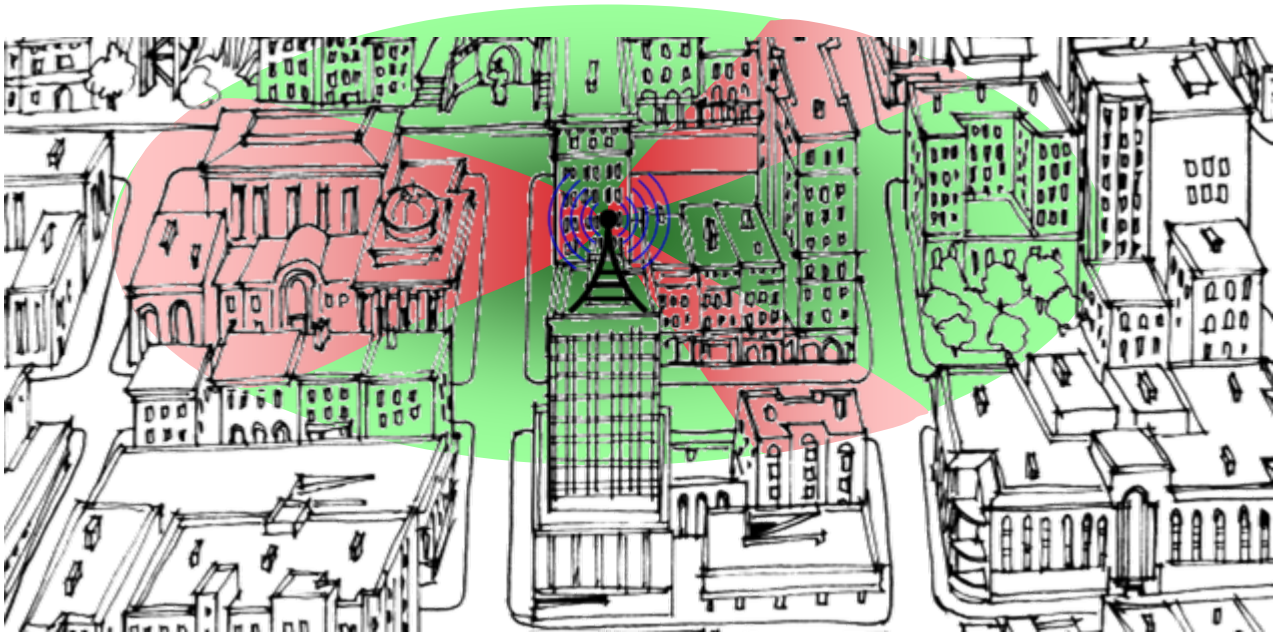

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PDX security

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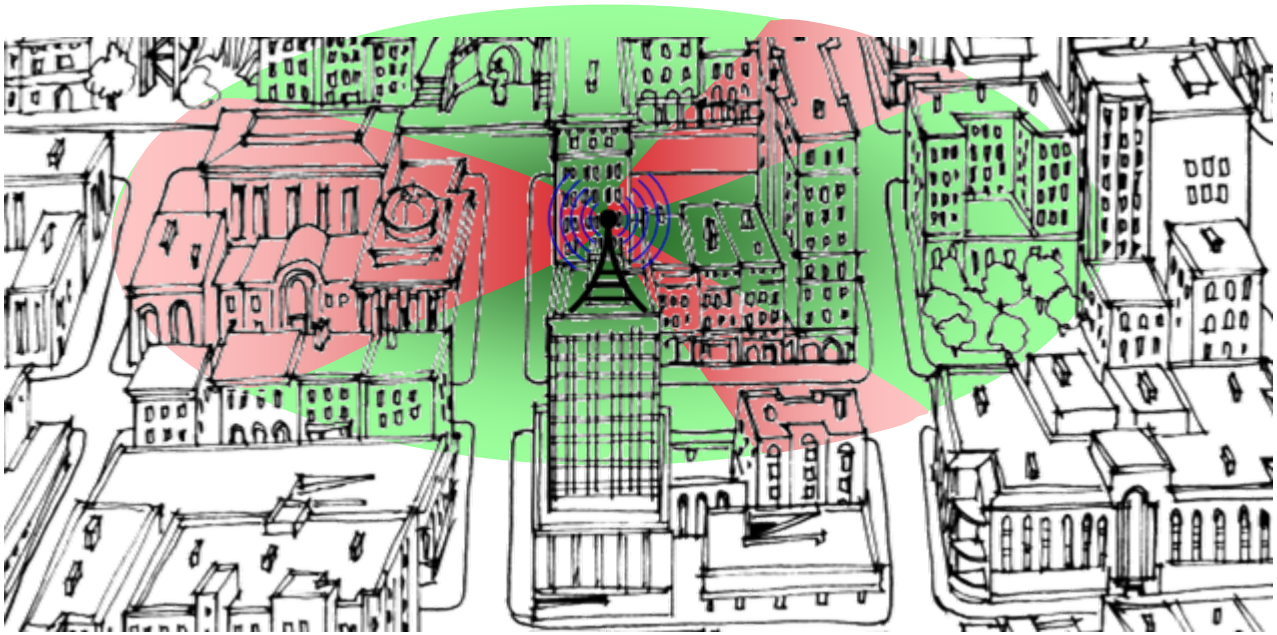

only free-to-air

PDX security

- Possible applications:
  - Digital television broadcasting (DVB-T2/S2/NGH/T2mobile)
  - Data broadcasting services with conditional access

Application scenario 3

- Secure Cooperative Multiple Access Channels

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- 3G and beyond cellular systems with intermediate nodes (relays and femtocells)

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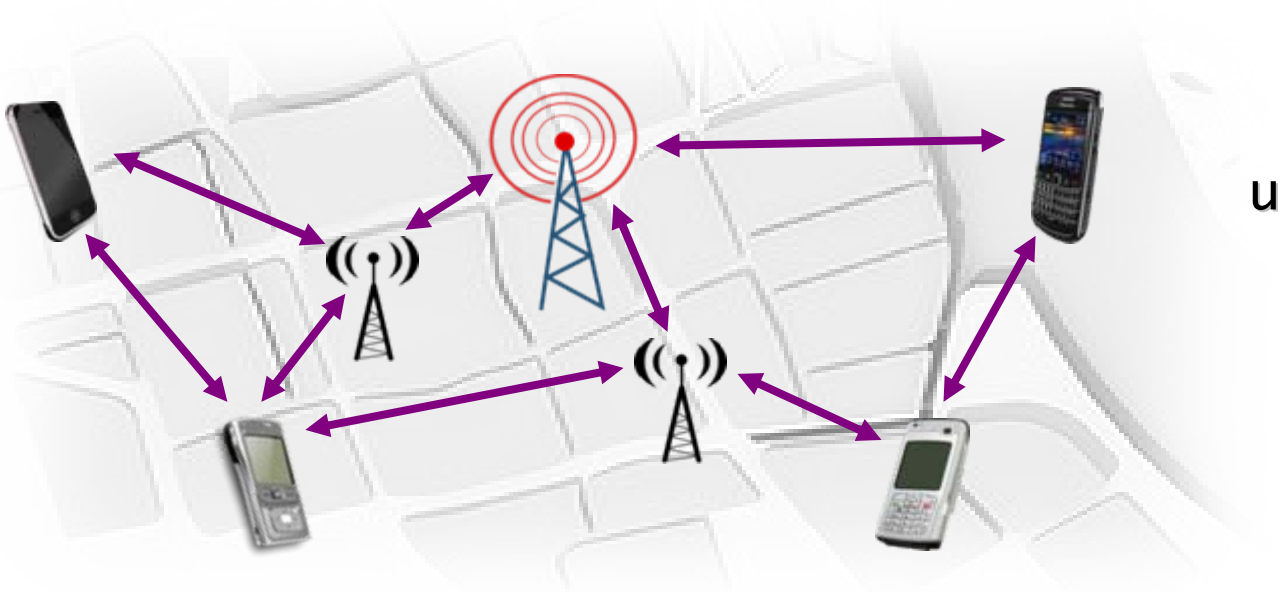

untrustworthy relays

- 3G and beyond cellular systems with intermediate nodes (relays and femtocells)
- Intermediate nodes are not controlled directly by the operator: possibly untrustworthy

Application scenario 3

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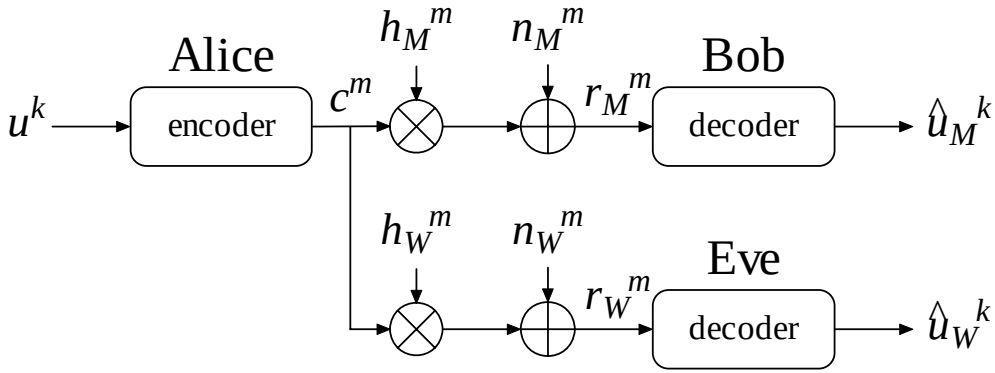
Physical Layer Security model

Wire-tap channel model



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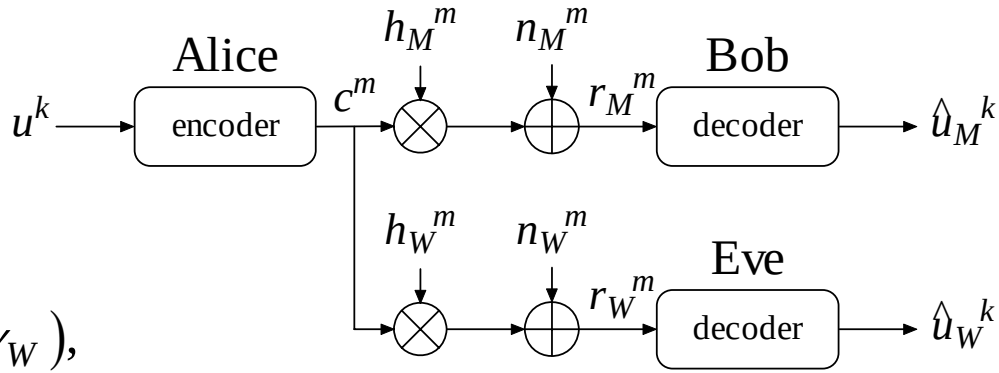

Secrecy Capacity

$$C_s = \sum_{\gamma_M > \gamma_W} \log(1+\gamma_M) - \log(1+\gamma_W),$$

$$\gamma_M = \left|h_M^n\right|^2 \frac{P}{N_M},\ \gamma_W = \left|h_W^n\right|^2 \frac{P}{N_W}.$$

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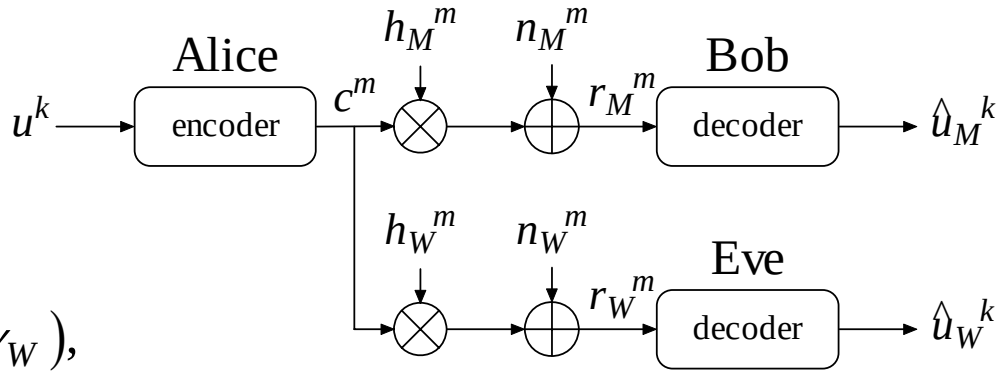

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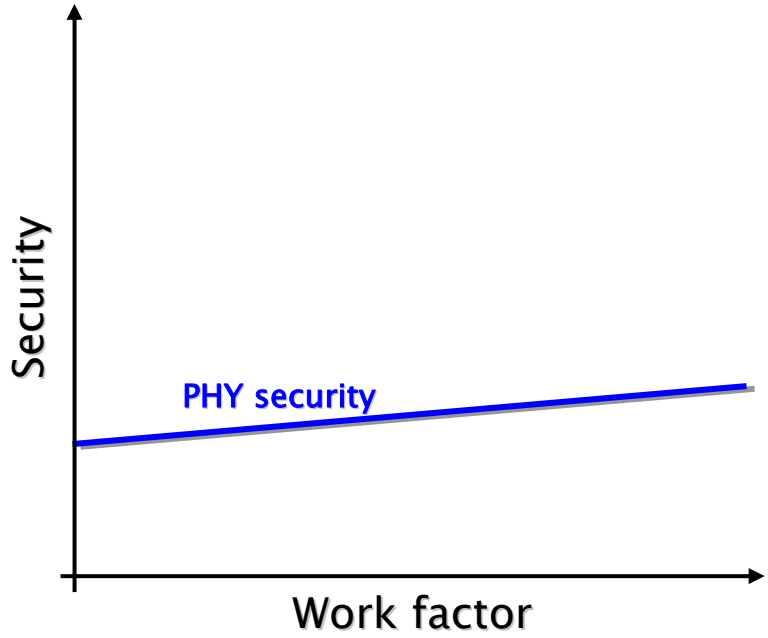

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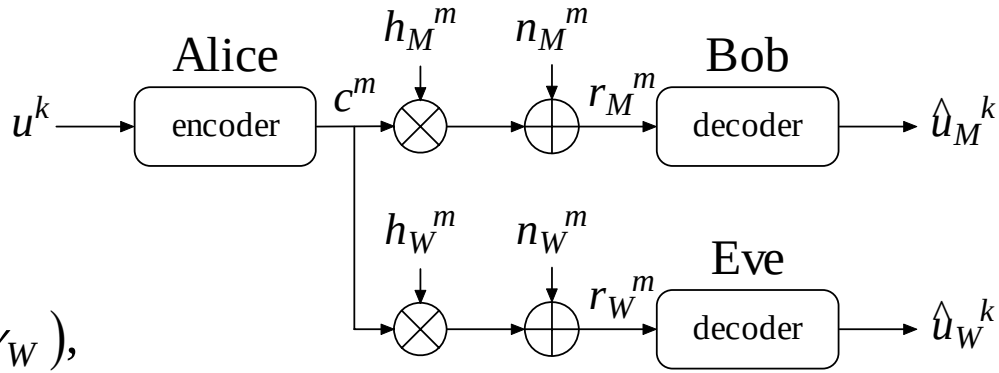

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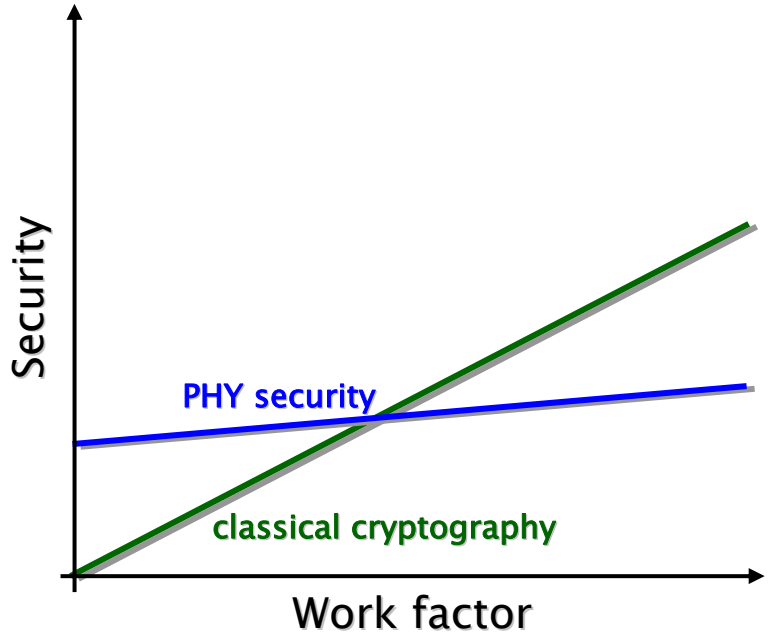
- Inherent wireless security exists
- Classical cryptography is only based on computational assumptions



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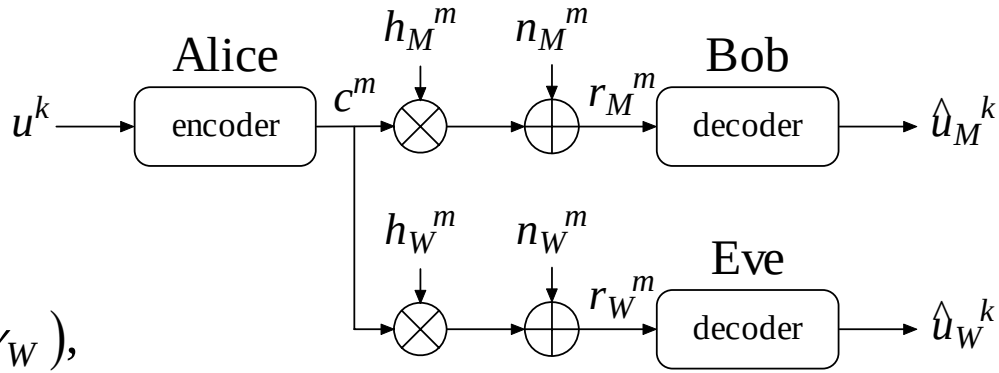

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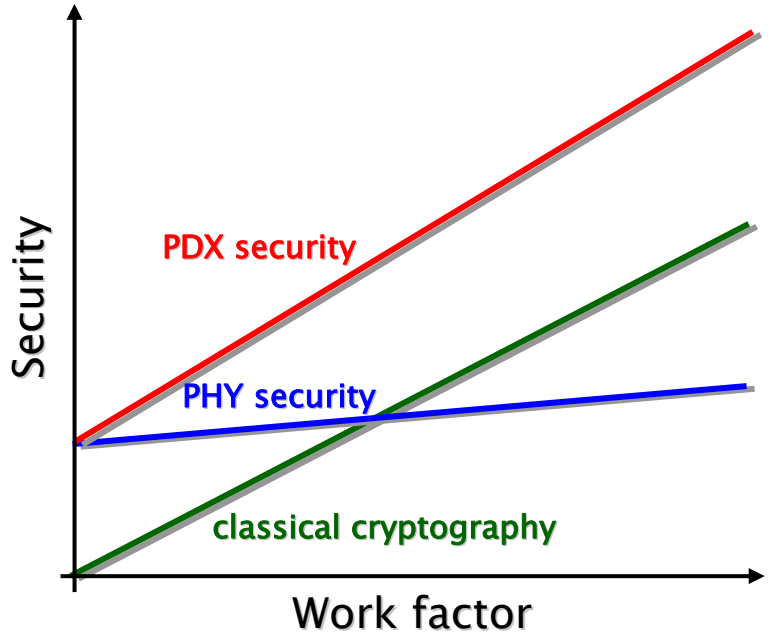
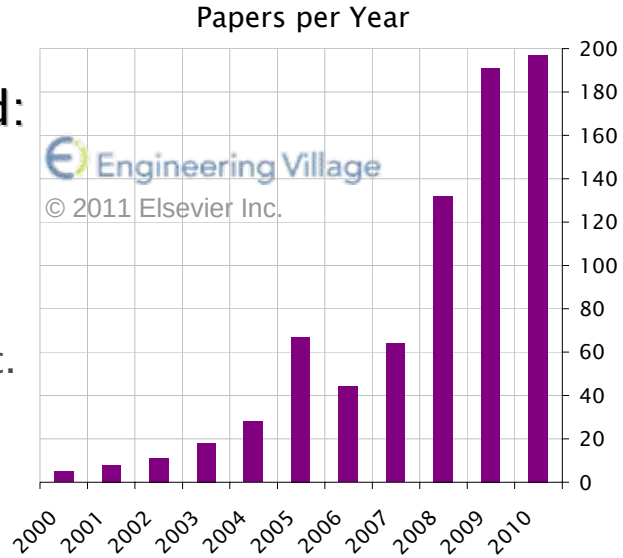
- Inherent wireless security exists
- Classical cryptography is only based on computational assumptions
- Exploiting the physical layer can enhance communication security



Physical Layer Security importance

- Physical layer security is a breakthrough in communication security paradigms:
  - Unconditional security (no computational assumptions)
  - Reinforcement of higher layer security protocols
  - No more need of pre-shared secret keys
  - Crucial for securing cooperative communications (future cellular networks)
- Locates within the topic of *homeland security*, strategic for the national economy (D.D. 27/09/2010 no. 584/ric)
- Well established and continuously growing field:
  - Dedicated workshops at top conferences
  - Specific books and special issues of international journals
  - 2011 IEEE Communications Soc. & Information Theory Soc. Joint Paper Award (M. Bloch, J. Barros, M. R. D. Rodrigues, S. W. McLaughlin)



State of the art

- The randomness of wireless channels can be exploited to provide information security at the physical layer (PHY)
- Theoretical limits of PHY security have been widely investigated
- Some practical schemes available only for toy channel models
- Emerging trend: PHY and Data Link cross-layer (PDX) schemes for integrated security
- Dominant techniques eligible for PDX security:
  - Channel coding (especially LDPC coding)
  - Orthogonal Frequency-Division Multiplexing (OFDM)
  - Cross-layer solutions with Automatic Repeat-reQuest (ARQ)

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Open Issues

- No efficient practical solutions for PDX security in most scenarios
- No publicly available tools for implementing and assessing PDX security schemes in wireless networks

Project goals

for the Scientific/Technical community

- New practical error protection and secrecy achieving codes tailored for wireless transmissions
- New protocols and optimization tools for PDX secure wireless transmission
- New network codes for PDX secrecy in cooperative systems and new detection tools against rogue nodes

papers, workshops, seminars, simulators, website

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- Practical PDX security solutions ready for existing and future wireless networks
- Software tools for implementing and assessing PDX security techniques

tech. reports, patents, software, testbeds

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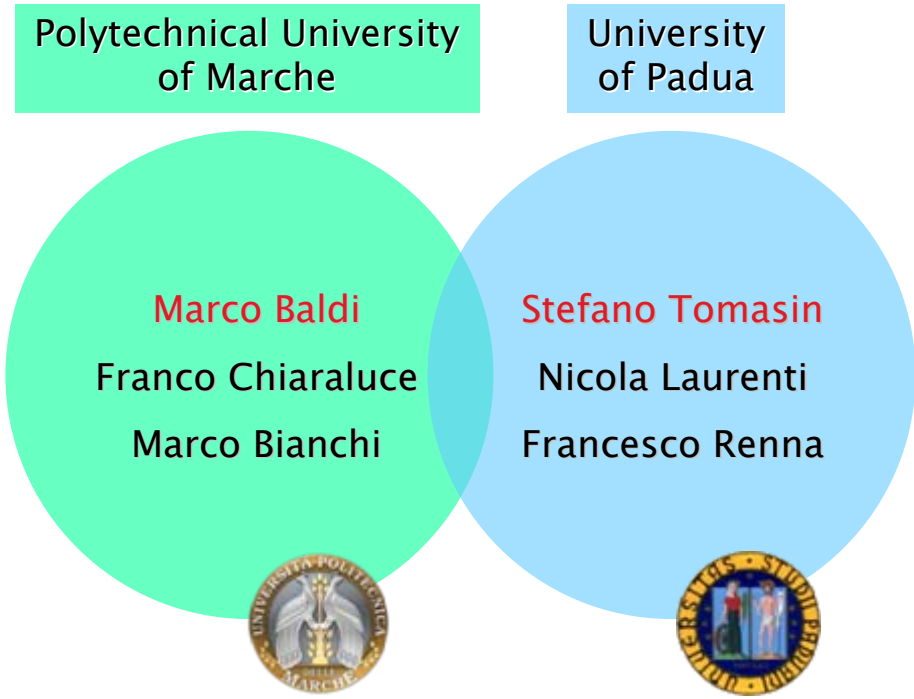
for Customers/Everyday life

- Wireless devices (based on commercial hardware) that implement PDX security
- Easier deployment of secure wireless networks (without pre-shared keys)

card drivers, website

Research group



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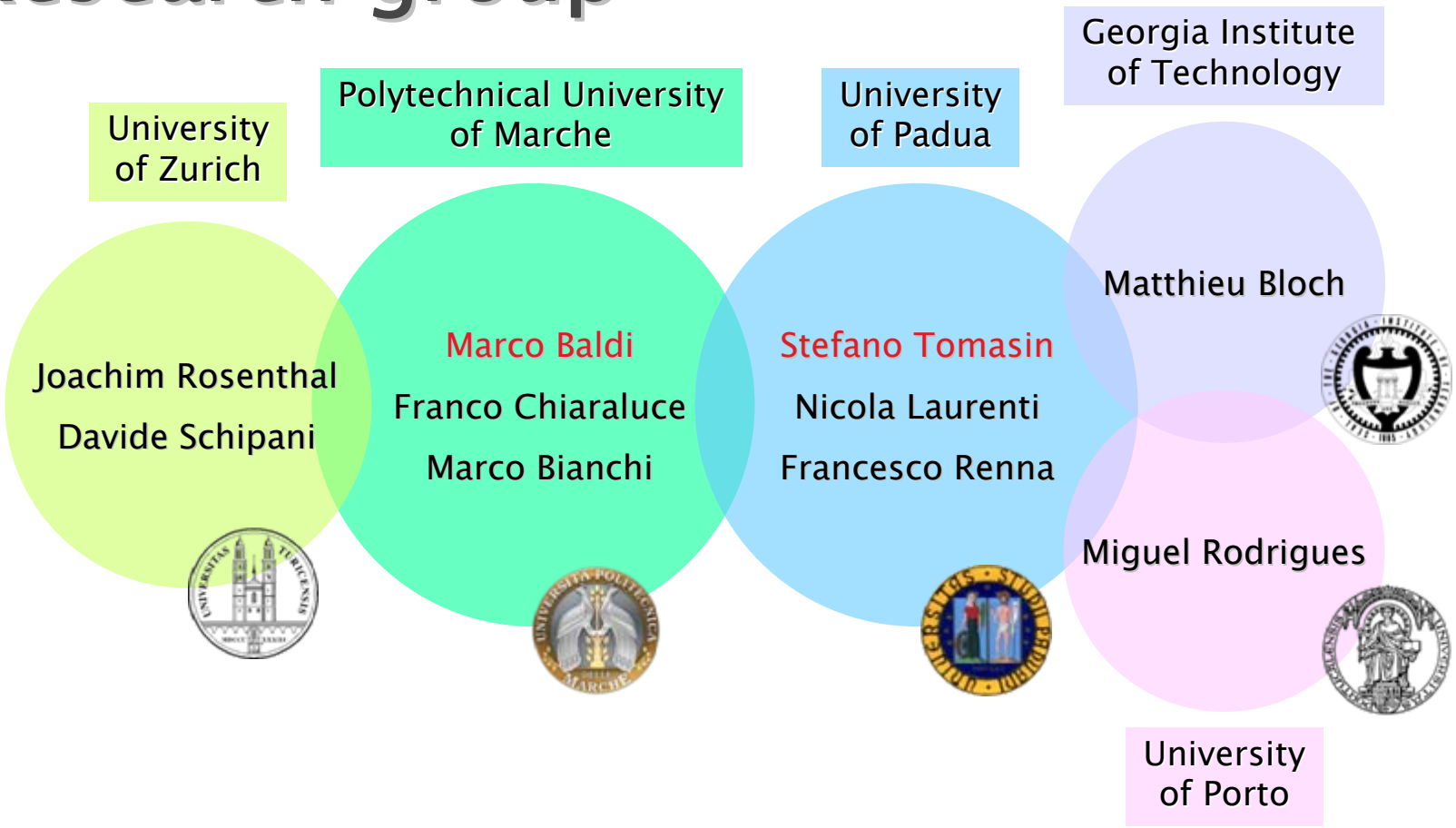

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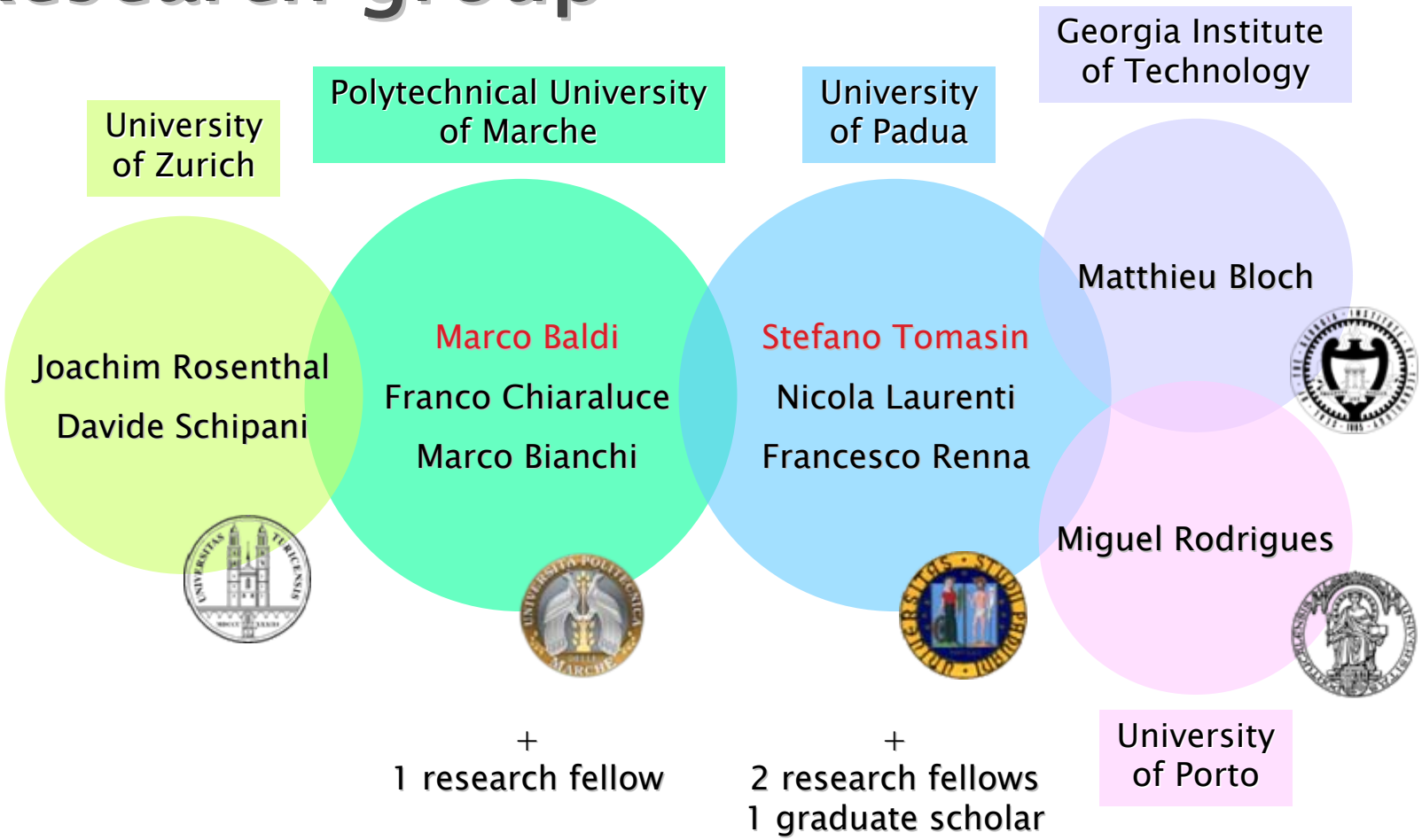

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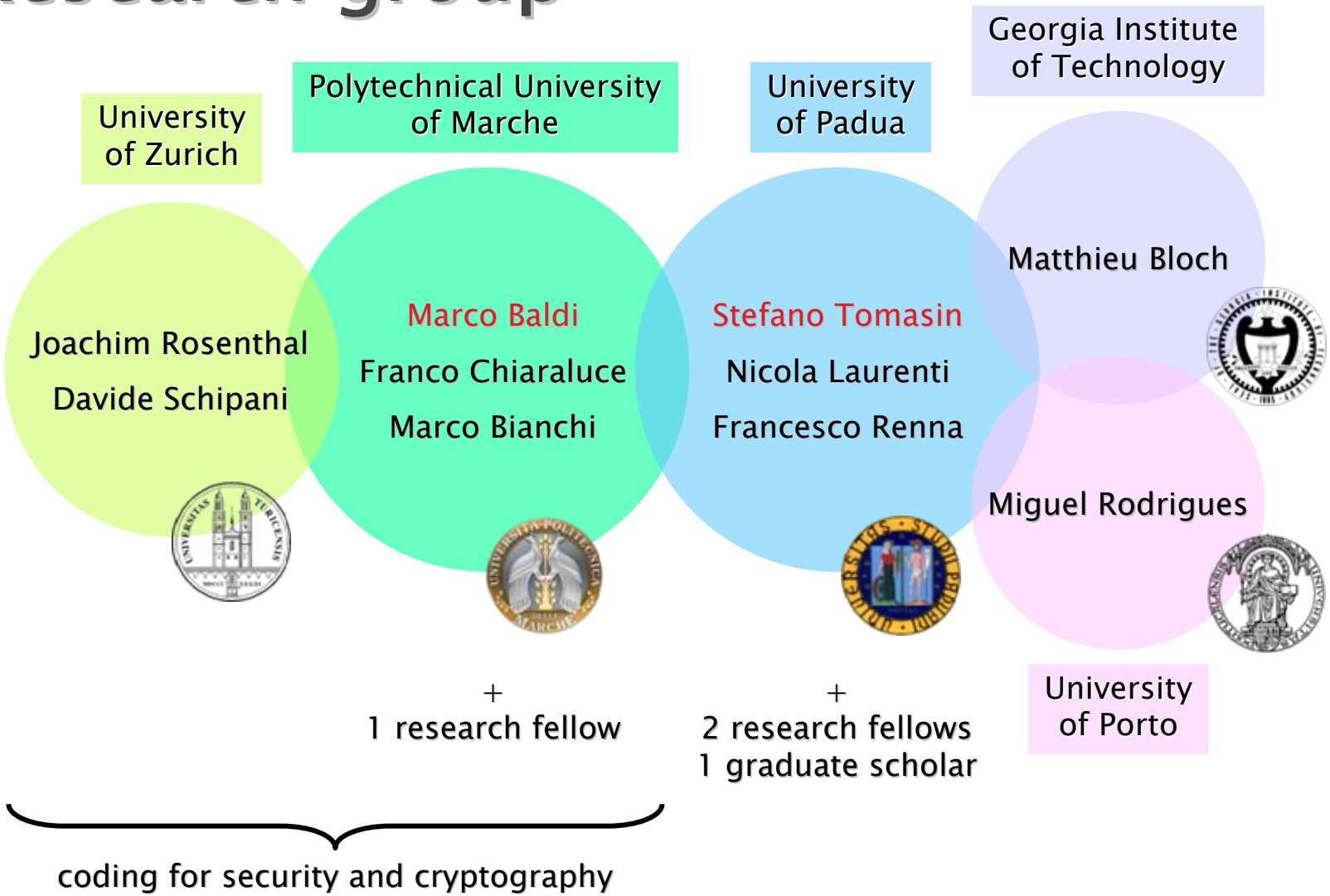

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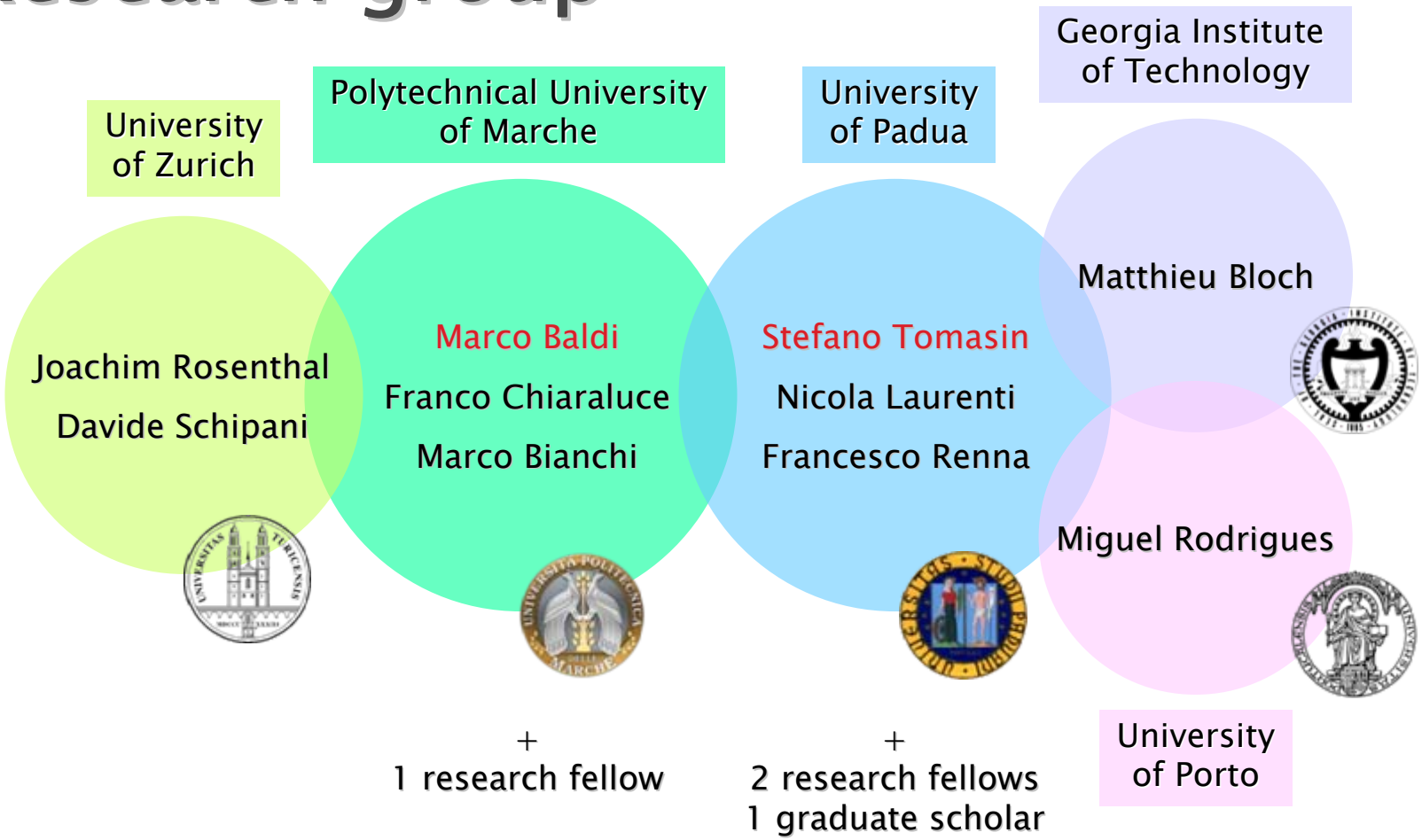
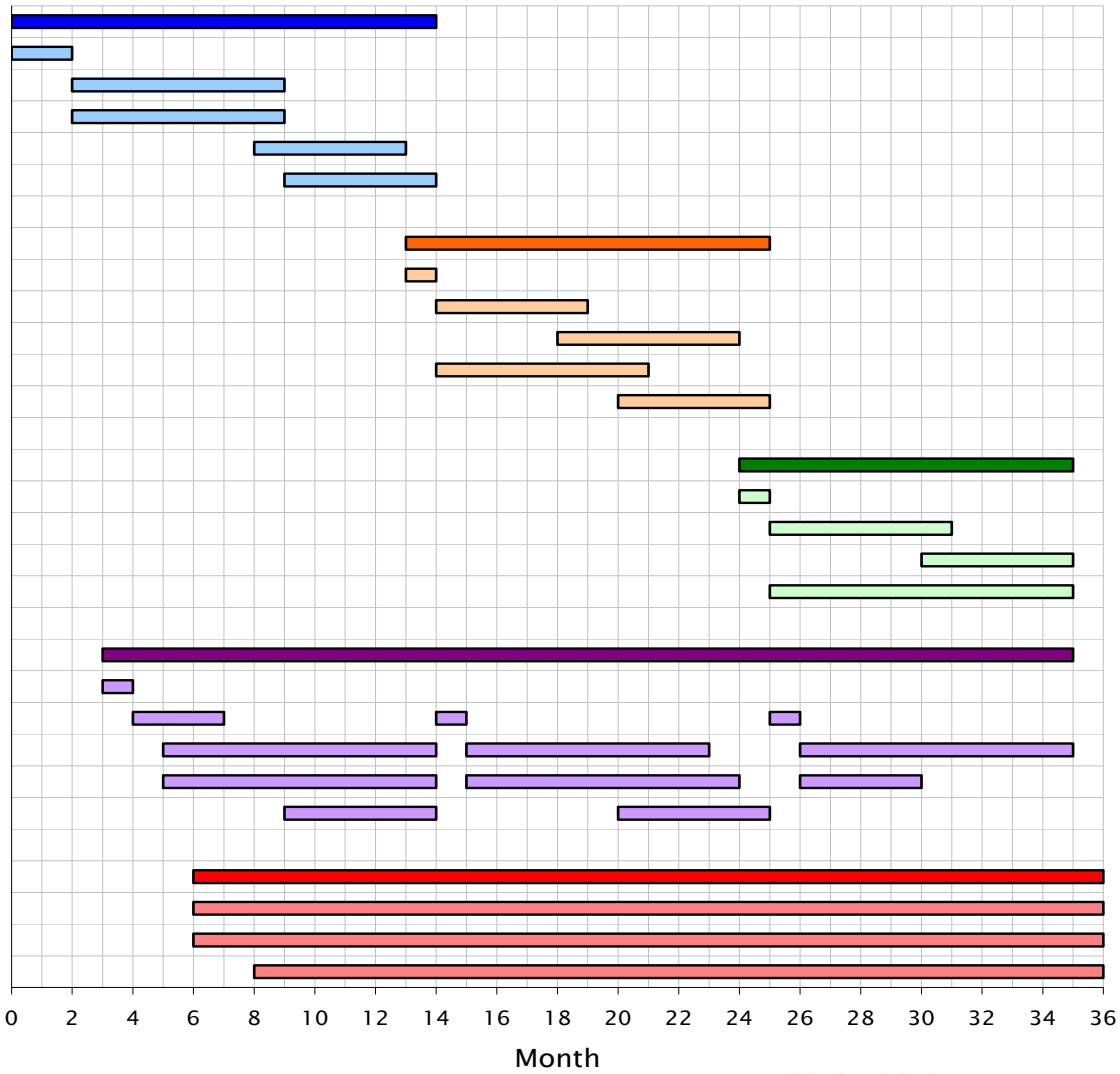


Some recent results

- Related scientific papers:
  - M. Baldi, F. Bambozzi, F. Chiaraluce, “On a family of circulant matrices for quasi-cyclic low-density generator matrix codes”, *IEEE Trans. Inf. Theory*, Sep. 2011.
  - M. Baldi, M. Bianchi, F. Chiaraluce, J. Rosenthal, D. Schipani, “A variant of the McEliece cryptosystem with increased public key security”, *Proc. WCC 2011*.
  - M. Baldi, M. Bianchi, F. Chiaraluce, “Increasing physical layer security through scrambled codes and ARQ”, *Proc. IEEE ICC 2011*.
  - M. Baldi, M. Bianchi, F. Chiaraluce, “Non-systematic codes for physical layer security”, *Proc. IEEE ITW 2010*.
  - S. Dehnie, S. Tomasin, “Detection of selfish nodes in networks using CoopMAC protocol with ARQ”, *IEEE Trans. Wireless Commun.*, Jul. 2010.
  - S. Tomasin, M. Levorato, M. Zorzi, “Steady state analysis of coded cooperative networks with HARQ protocol”, *IEEE Trans. Commun.*, Aug. 2009.
  - F. Renna, M. Bloch, N. Laurenti, “Semi-blind key-agreement over MIMO fading channels”, *Proc. IEEE ICC 2011*.
  - F. Renna, N. Laurenti, H.V. Poor, "Physical layer secrecy for OFDM systems”, *Proc. EW 2010*.
  - F. Renna, N. Laurenti, H.V. Poor, "High SNR secrecy rates with OFDM signaling over fading channels”, *Proc. PIMRC 2010*.

- Related patents:
  - M. Baldi, M. Bianchi, F. Chiaraluce, J. Rosenthal, D. Schipani, “Method and apparatus for public-key cryptography based on error correcting codes”, *Swiss Patent Application*, Ref. P160183, July 2011.
  - A. Morello, S. Tomasin, P. Baracca, L. Vangelista and N. Benvenuto, “Method and apparatus for receiving numerical signals modulated by frequency division multiplexing”, *WIPO Patent Application*, WO 2011/024118(A2), March 2011.
  - M. Butussi and S. Tomasin, “Interpolated channel estimation for mobile OFDM systems”, *WIPO Patent Application*, WO 2010/081896, July 2010.

Project organization



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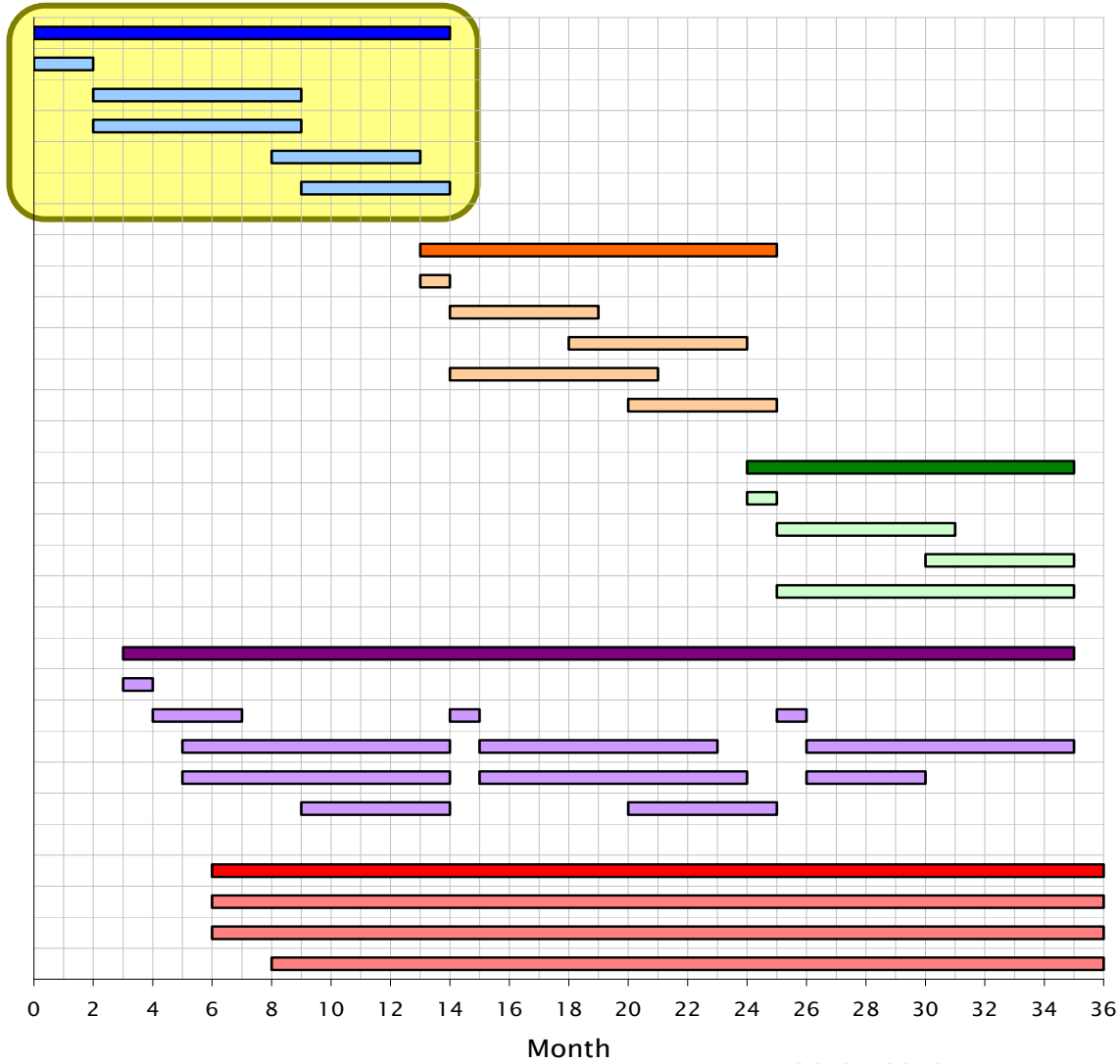
WP1: PDX security for point to point transmissions

- M1.1: Definition of the system model and parameters
- M1.2: Physical layer security through OFDM techniques
- M1.3: Physical layer security through coding techniques
- M1.4: Physical layer security through HARQ techniques
- M1.5: Joint usage of OFDM, coding and HARQ



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WP2: PDX security for the confidential broadcast channel

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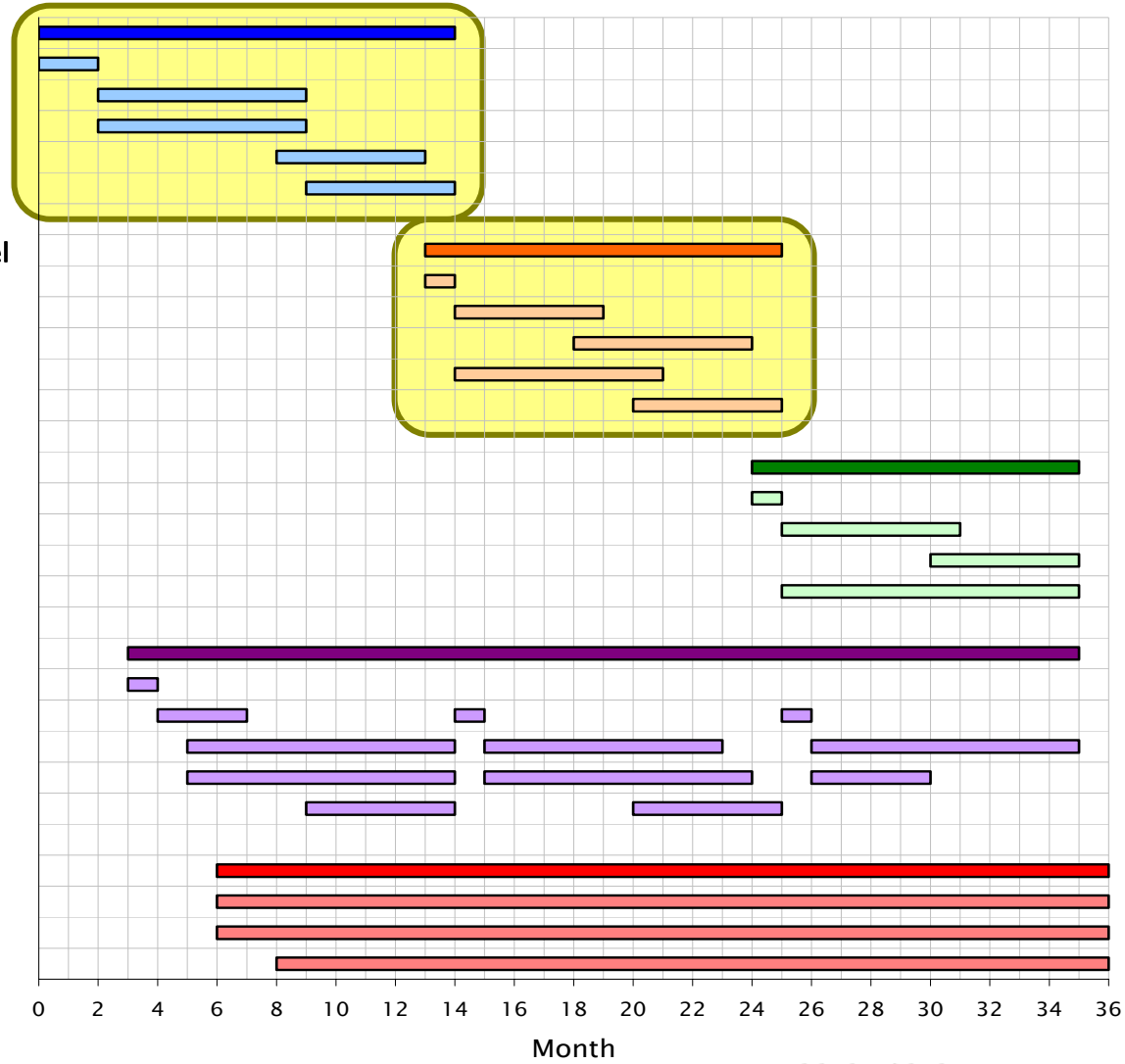

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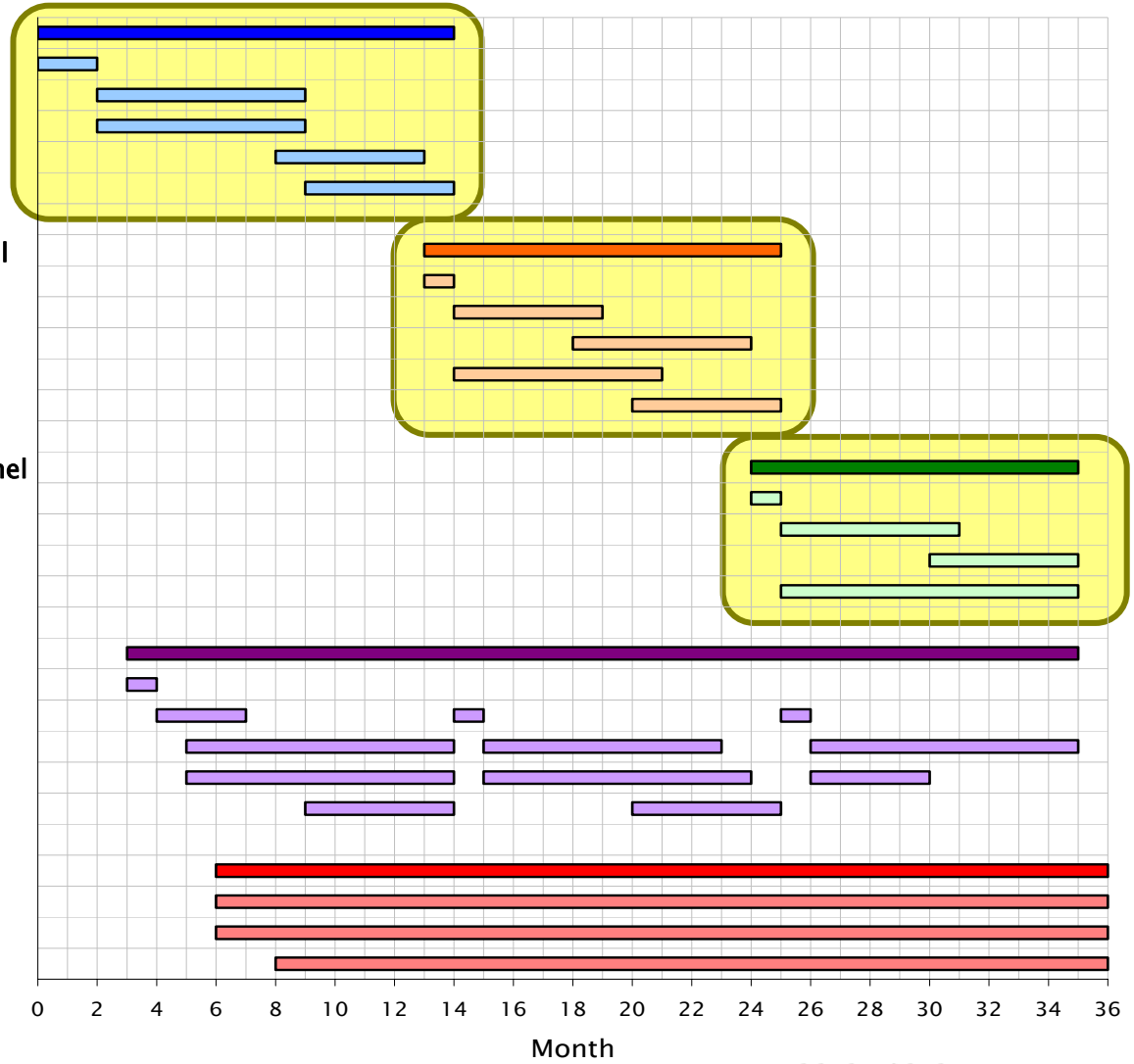

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WP4: Evaluation tools for PDX security
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- M4.3: Implementation of the coding and decoding routines
- M4.4: Implementation of the OFDM simulation routines
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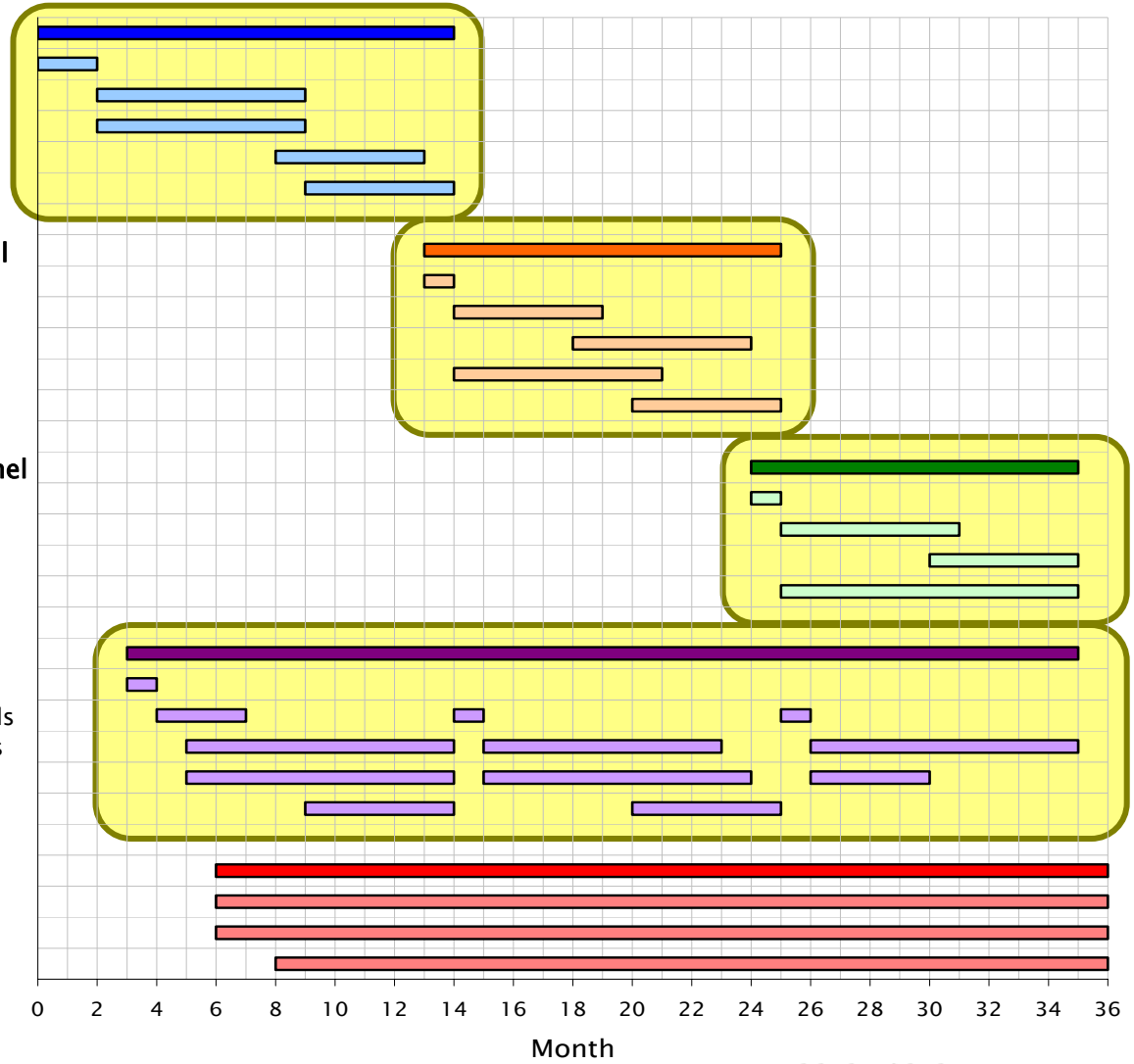

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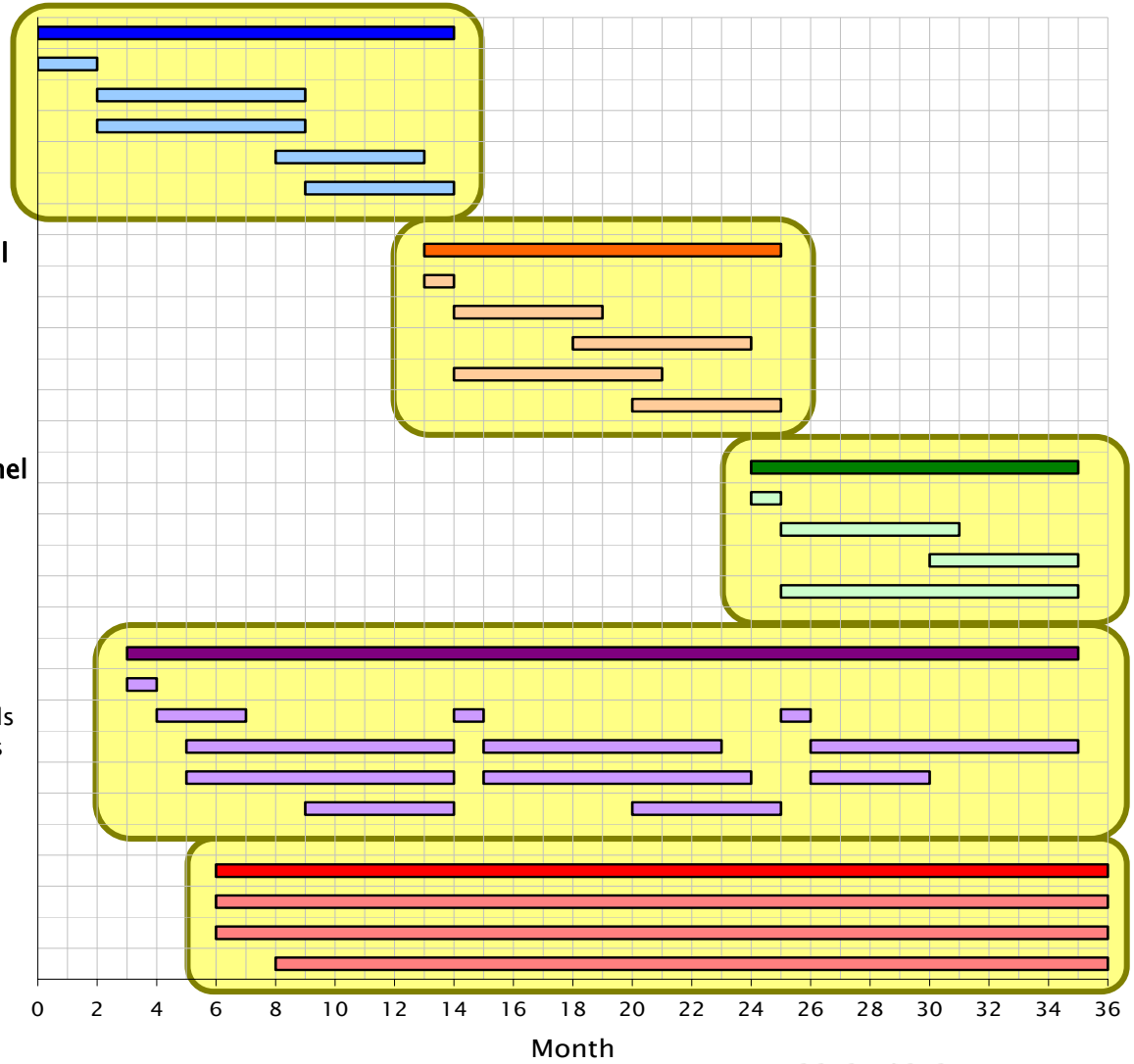
WP5: Results dissemination and scientific networking
- M5.1: Preparation and submission of scientific papers
- M5.2: Development and publication of the project website
- M5.3: Scientific exchange with other research institutions



FUTURO IN RICERCA

Outcomes per WP

- WP1 (PDX security for point to point transmissions)
  - Definition, study and simulation of new PDX techniques for wireless networks
  - Choice of coding techniques, OFDM and modulation schemes
  - Design of HARQ techniques for increased security
- WP2 (PDX security for confidential and common transmissions over the broadcast channel)
  - Design of selective coding techniques for different levels of PDX security
  - Design and optimization of algorithms for resources allocation in OFDM
  - Design of HARQ techniques for the broadcast channel
- WP3 (PDX security for cooperative multiple access channel)
  - Study of cooperative coding under the PDX security viewpoint
  - Design of network coding techniques to be integrated in the system
  - Definition of a reputation management system to improve cooperation
- WP4 (Evaluation tools for PDX security)
  - Development of a software simulator of the whole system (in C++ or Matlab/Octave)
  - Development of modified drivers for existing network cards
- WP5 (Results dissemination and scientific networking)
  - Preparation of scientific papers and submission to international journals and conferences
  - Application for international patents on security techniques and principles
  - Implementation of the project website for disseminating the results and the software tools
  - Organization of seminars, workshops and scientific visits

Outcomes per WP

- WP1 (PDX security for point to point transmissions)
  - Definition, study and simulation of new PDX techniques for wireless networks
  - Choice of coding techniques, OFDM and modulation schemes
  - Design of HARQ techniques for increased security

Year 1

- WP2 (PDX security for confidential and common transmissions over the broadcast channel)
  - Design of selective coding techniques for different levels of PDX security
  - Design and optimization of algorithms for resources allocation in OFDM
  - Design of HARQ techniques for the broadcast channel
- WP3 (PDX security for cooperative multiple access channel)
  - Study of cooperative coding under the PDX security viewpoint
  - Design of network coding techniques to be integrated in the system
  - Definition of a reputation management system to improve cooperation
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Year 2

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Thank you