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# Advances in Cryptography

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# Introduction of CRG

**Cryptology Research Group**:

- small group of around 10 people,
- Professors, Ph.D.s and postdocs,
- part of Department of Telecommunications, BUT,
- forms the SIX Security Laboratory,
- focused on basic and applied research in crypto,
- provides security-related services in ICT.

# Activity Overview

**R&D in Cryptographic Protection:**

- cryptographic design of new protocols and schemes,
- access control systems,
- secure authentication systems,
- privacy-enhancing schemes,
- encryption systems for data transfer and storage.

**Security System Implementation:**

- application development for smart-cards,
- application development for smart-phones (Android, iOS),
- protection of low-performance  systems (sensors, controllers...).

# Services: High-Load Testing and Benchmarking

Extreme-load testing of devices using specialized HW:

- tests with more than 1 mil. HTTP GET requests per second,
- 300 000 HTTPS requests per second, throughput 20 Gb/s,
- up to 30 millions sustained connections,
- real user behavior simulation, web clients simulation,
- more information by Lukáš Malina: “Stress testing and distributed denial of service testing of network infrastructures” at 13:20.


# Current Areas of Research

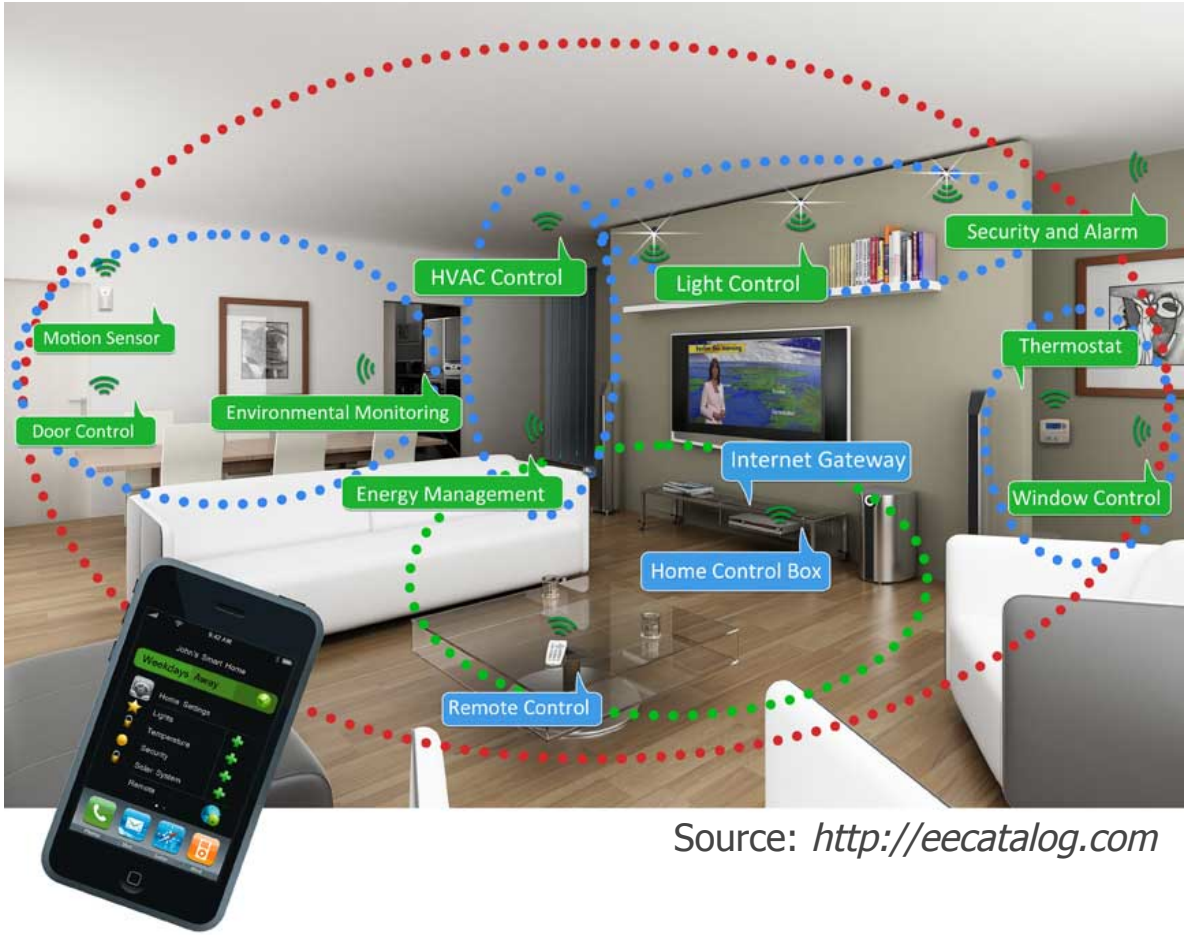
**Research into lightweight cryptography:**

- done in cooperation with Honeywell, s.r.o.,
- focused on adding security features to “slow devices”,
- includes final implementations on microcontrollers.

**Research into privacy-enhancing cryptography:**

- both basic and applied research into modern cryptographic protocols,
- done in cooperation with many partners from U.S., EU, Czech Republic,
- includes final implementations on smart-cards, mobile phones.

# Research into Lightweight Cryptography - Introduction




Source: *http://eecatalog.com*

# Research into Lightweight Cryptography I

**What is "lightweight cryptography"?**

- provides secure encryption on computationally (and memory) restricted devices,
- algorithms designed to be efficient in using CPU, RAM and codesize,
- tradeoff between CPU and memory usage,
- many algorithms available, each suits different scenario.

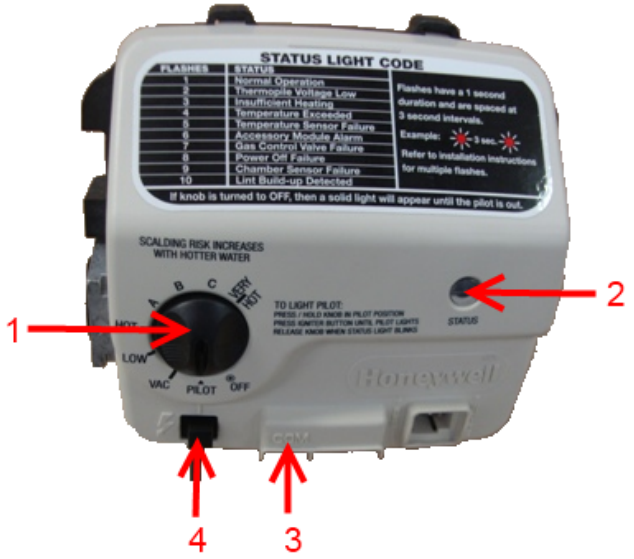
**What are our goals regarding lightweight cryptography?**

- we analyze, implement and benchmark lightweight algorithms on concrete devices to provide data necessary for a suitable algorithm selection,
- we choose algorithms for a real-world implementation for our industry partners,
- we design protocols for cryptographically secured home installations.

# Research into Lightweight Cryptography II

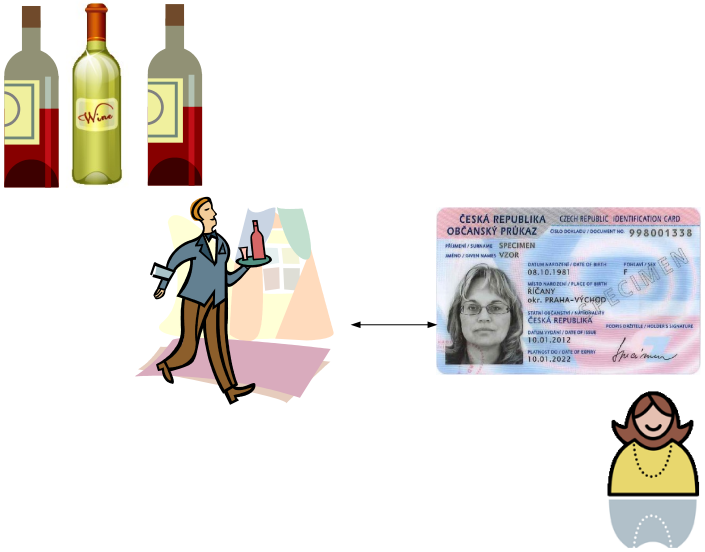
**What are our preliminary results?**

- during 2013, we analyzed existing block ciphers, implemented them on targeted hardware (MSP430F2274) and ran benchmarks,
- XTEA, IDEA, BlowFish, AES, Clefia, Present, Noekeon, RC5, RC6 and BeepBeep ciphers were benchmarked,
- codesize, memory size and speed were evaluated,
- the design of a cryptographically protected communication protocol has been started.

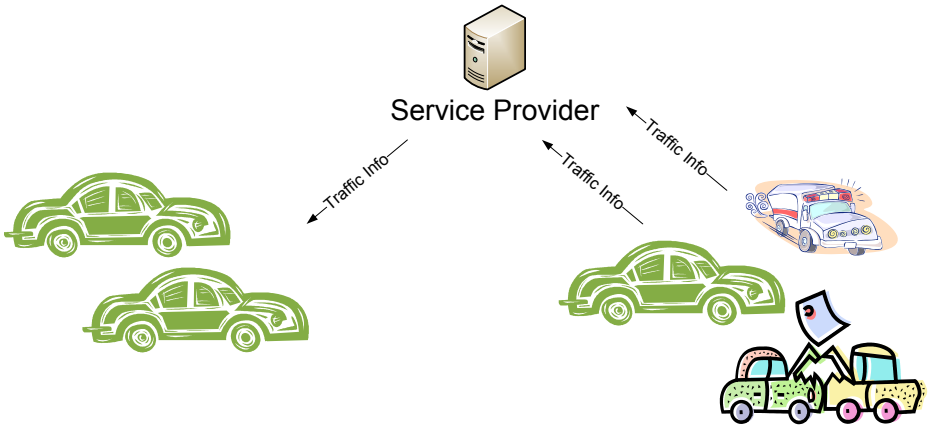


# Research into Privacy-Enhancing Cryptography - Intro

Bar scenario:
anonymous age proofs.




Car2Car scenario:
anonymous membership proofs.

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# Research into Privacy-Enhancing Cryptography I

**What is "privacy-enhancing cryptography"?**

- Special algorithms and cryptographic schemes which protect personal data and digital identity.
- Cryptographic tools which protect us against digital tracing, profiling, identity thefts, personal information leaks etc.
- Applications: electronic ID (eID) cards, passports, eVoting, transportation cards, access control systems, Internet authentication, etc.
- Required by U.S. and EU institutions (NSTIC, ENISA).

**What are our goals regarding privacy-enhancing cryptography?**

- Design novel, original cryptographic protocols with better privacy protection.
- Provide new features missing in existing schemes (such as revocation).
- Implement protocols in an efficient, *practical* way.

# Research into Privacy-Enhancing Cryptography II

**Privacy-enhancing cryptography at BUT**

- **Basic research stage:**
  - design of a novel cryptographic scheme,
  - based on advanced cryptography (provable cryptography, zero-knowledge non-interactive proofs)
  - in cooperation and with consultations with University of Minnesota, USA, NIST and IBM Zurich
- **Applied research stage, implementation:**
  - implementation of protocols on smart-cards,
  - significant protocol modifications for optimization,
  - done with industry partner OKsystem.


# Research into Privacy-Enhancing Cryptography III

## Privacy-enhancing cryptography at BUT – results:

**User** | **Verifier**

$A_{seed} = g_1^{w1} g_2^{w2} g_3^{wRR} \bmod n$

$K_S \in_R \{0,1\}^l$
$A = A_{seed}^{K_S} \bmod n$
$C_1 = g_3^{K_S w_{RR}} \bmod n$
$C_2 = g_3^{K_S} \bmod n$
$r_1, r_2 \in_R \{0,1\}^{m+k+3l}$
$r_3 \in_R \{0,1\}^{m+k+4.5l}$
$r_S \in_R \{0,1\}^{m+k+l}$
$\bar{A}_{seed} = g_1^{r1} g_2^{r2} g_3^{r3} \bmod n$
$\bar{A} = A_{seed}^{r_S} \bmod n$
$\bar{C}_1 = g_3^{r3} \bmod n$
$\bar{C}_2 = g_3^{r_S} \bmod n$

$\xrightarrow{A, \bar{A}, \bar{A}_{seed}, C_1, C_2, \bar{C}_1, \bar{C}_2}$

$\xleftarrow{e \in_R \{0,1\}^k}$

$z_1 = r_1 - eK_S w_1$
$z_2 = r_2 - eK_S w_2$
$z_3 = r_3 - eK_S w_{RR}$
$z_S = r_S - eK_S$

$\xrightarrow{z_1, z_2, z_3, z_S}$

$C_1 \stackrel{?}{\neq} C_2^{rev} \bmod n$
$\bar{A}_{seed} \stackrel{?}{\equiv} A^e g_1^{z1} g_2^{z2} g_3^{z3} \bmod n$
$\bar{A} \stackrel{?}{\equiv} A^e A_{seed}^{z_S} \bmod n$
$\bar{C}_1 \stackrel{?}{\equiv} C_1^e g_3^{z3} \bmod n$
$\bar{C}_2 \stackrel{?}{\equiv} C_2^e g_3^{z_S} \bmod n$


| Hardware Specification | |
|---|---|
| Chip | SLE78CLXxxxPM |
| CPU | 16 bit |
| Int./Ext. clock | 33 MHz/7.5 MHz |
| RAM Memory | 1088+960 B |
| ROM/EEPROM | 280 kB/60 kB |
| Modular API | Yes |

# Research into Privacy-Enhancing Cryptography III

**Privacy-enhancing cryptography at BUT – results:**

- original cryptographic scheme has been designed and published,
- complex cryptographic protocols are running on off-the-shelf smart-cards,
- system is fully functional, providing users with the ability to anonymously, untraceably prove their attributes (such as age, citizenship, driving license ownership) to electronic verifiers,
- system is ready to be deployed in privacy-preserving access control systems,
- currently, only two comparable systems exist: U-Prove from Microsoft and Idemix from IBM.

# Research Results and Partners

Research Projects in 2014:

- „Cryptographic primitives for secure authentication and digital identity protection“,
- „Integration Server with Cryptographic Protection“,
- „System for Cryptographic Protection of Electronic Identity “,
- „Application of Modern Cryptographical Methods to Telematics Systems “.

Selected Recent Papers:

- Optimization of Power Analysis Using Neural Network, CARDIS 2013, Berlin, Germany, Springer LNCS.
- Unlinkable Attribute-Based Credentials with Practical Revocation on Smart-Cards, CARDIS 2012, Graz, Austria, Springer LNCS.
- Short-Term Linkable Group Signatures with Categorized Batch Verification, FPS 2012, Montreal, Canada, Springer LNCS.

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# Contacts

## Thank you for attention!

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