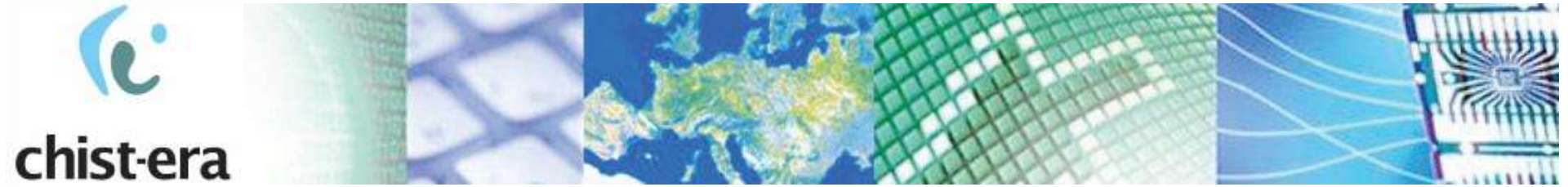
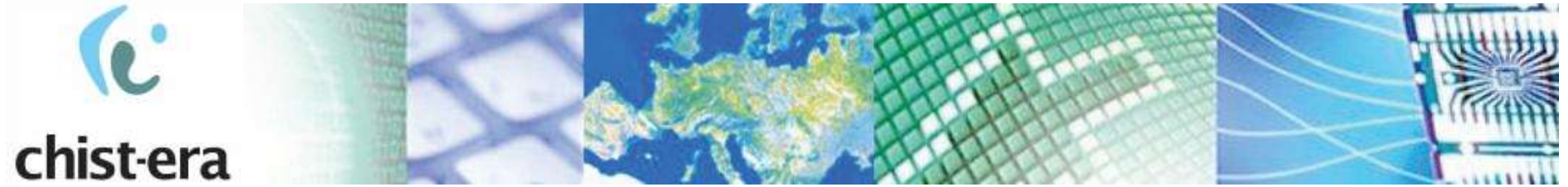


CHIST-ERA Projects Seminar
Day 2, Cross Topics
G-ICT: Towards Zero Power ICT

Erol Gelenbe

Bern, April 29th, 2016

FUNDING OPPORTUNITIES from the
FUTURE & EMERGING TECHNOLOGIES scheme



ECROPS:
Minimum Energy & Maximum Harvesting for Energy Optimal Communications

- Developed Unified Discrete Probability Models for Energy-DataFlow, Transmission & Optimisation (Energy Packet Networks): Arrival Processes for Energy & Data,
  {Queues & Servers} → {Batteries, Data Buffers}
  Enables System Engineering, Design and Optimisation
- Demonstrated Wearable On-Chip Hardware Harvesters and Communication Energy Optimisers

EURECOM
Sophia Antipolis

METU - Ankara

Imperial College London

CTTC Barcelona

FUNDING OPPORTUNITIES from the FUTURE & EMERGING TECHNOLOGIES scheme

ECROPS
Major achievements and output

Goal: Communicate with Zero Non-Renewable Energy

- - Demonstrated On-Board-On-Chip Real Hardware Harvester and Optimiser
  - Developed Energy Packet Networks with On-Line Real-Time Decision Algorithms
  - Intrduced the “Crazy Idea” of Femto-Power Communications with Spins
- **3 ERCs – Haluk Kulah, METU; Deniz Gunduz, Imperial; David Gesbert, Eurecom**
- **Marie Sklodowska-Curie Network “Sustainable Cellular Networks Harvesting Ambient Energy - SCAVENGE” 2016- 2020 - Imperial & CTTC, Athonet, National Instruments, Toshiba Research, Worldsensing .. H2020; Imperial-MoD Project for ICT Energy Optimisation; UK Links Project Imperial & Sabanci University on Harnessing Renewable Energy Sources for Communications”; Non-funded joint work: University of Venice Ca` Foscari , NYU and NJIT**
- 2 Major Keynotes (WCNC 2014, COMPSAC 2014), 2 best paper awards (GreenNets & WCNC 2015). > 20 IEEE and ACM journal papers and > 40 conference papers
- IEEE R8 Best Young Researcher in Communications (2015), Election to Royal Acad. of Belgium + Polish Acad. of Sciences, “In Memoriam Dennis Gabor Award”

GEMSCLAIM: Greener Mobile Systems By Cross Layer Integrated Energy Management

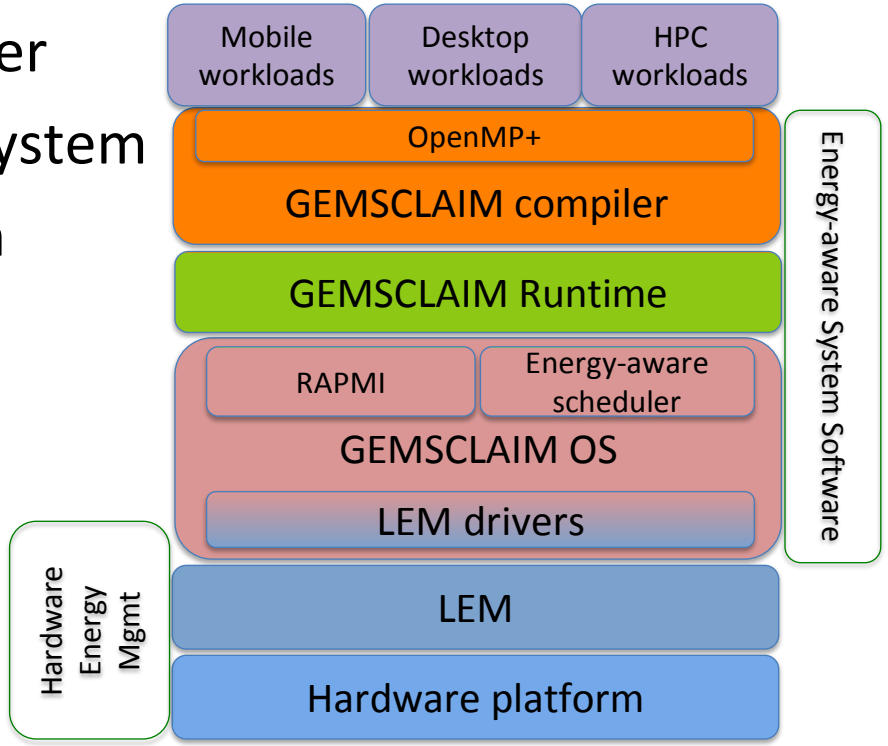
chist-era

Cross layer energy management and optimization for mobile devices: HW/simulator, OS, compiler

- ✓ Energy-aware optimizing compiler
- ✓ Energy-proportional operating system
- ✓ Customizable HW modeling with energy monitoring facilities

Potential impact

- ✓ control trade-off between energy and performance
- ✓ additional 30 % energy savings for mobile terminals



universität innsbruck

Queen's University Belfast

RWTH AACHEN UNIVERSITY

UPT Universitatea Politehnica Timişoara

GEMSCLAIM
Major Achievements and Output

- Extension of OpenMP to control energy/runtime trade-off
- Per thread energy accounting of off-core HW components
- OS scheduling based on energy slices
- Bi-directional control interface between OS and applications
- Parallelized System-C simulator
- Energy savings of up to 70 % for mobile terminals

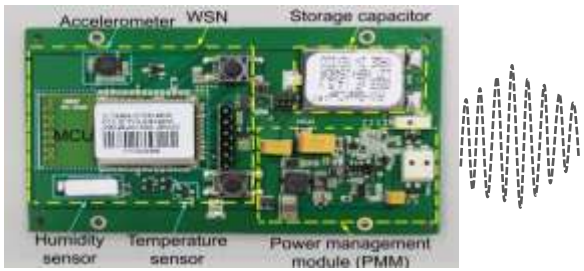
- Open source Gemsclaim SW
- Launched FETHPC AllScale project
- Simulator used as part of spin-off companies
- 34 publications

SMARTER
Major achievements and output

smarter

Smart Multifunctional Architecture & Technology

for Energy-aware wireless sensoRs



Project SMARTER
Major achievements and output

- **Goal:** Autonomous battery-free wireless sensor network (WSN)

Main results:

- **State-of-the-art high-performance microsupercapacitor technology**
- **Heterogeneous kapton-based flexible substrate technology**
- **Three demonstrators:**
  - ✓ High-efficiency piezoelectric energy-harvesting WSN powering
  - ✓ Multi-functional (sensing+harvesting) single-transducer architecture
  - ✓ Ultra low-power UWB communication
- **Publications:** 16 journals, 27 conferences

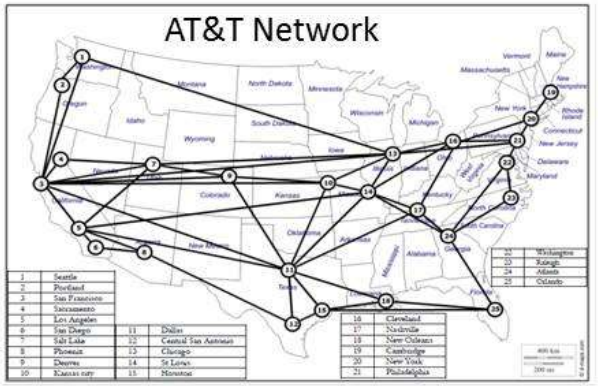
SwiTching And tRansmission (STAR)

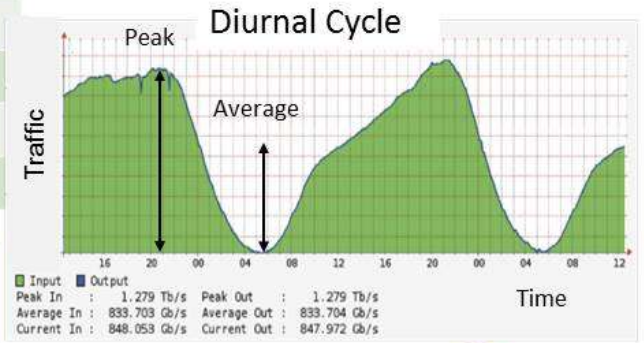
chist-era Jaafar Elmirghani, Adrian Wonfor, Artur Lason, Laurent Lefevre

GreenTouch™ Celebration
18 June 2015 • New York City

WCAN Core GreenMeter

2020 Technologies	Improvement
Business as usual (BAU)	4.23x
GreenTouch equipment innovations - Optical interconnects - Optimised packet processing - Energy optimised transponders	4.73x
Protection energised only when needed	1.96x
Router bypass & sleep equipment during off-peak	2.13x
Optimised line rate (40G, 100G, 400G, 1T)	1.21x
Optimised network direct path topology	1.43x
Optimised distributed cloud and virtualisation	2.19x
Overall efficiency improvement	**316x**





GreenTouch™

AGH Inria INVENTORS FOR THE DIGITAL WORLD UNIVERSITY OF CAMBRIDGE UNIVERSITY OF LEEDS

STAR Achievements

- 75 publications, 3 major awards

Awards

- Greentouch GreenMeter II study: white paper was published in June 2015
- Awards (2015/2016)

1. The STAR work on GreenMeter core network energy saving mechanisms led by Prof. Elmirghani has won the 2015 GreenTouch 1000x award “for pioneering research contributions to the field of energy efficiency in telecommunications” , international competition.

2. The IEEE Communications Society awarded Prof. Elmirghani the 2015 Transmission, Access and Optical Systems outstanding service award for "Leadership and Contributions to the Area of Green Communications", 2015, international competition.
3. Prof. Elmirghani together with six colleagues from GreenTouch has received the prestigious 2016 Edison Award under the Collective Disruption category, international competition

Highlights

- 6 new mechanisms for energy efficiency adopted by GreenTouch
- SOA optical switch with world-record number of optical components integrated (1000 components)
- SDN-based framework for energy traffic management
- New energy efficient protocols for cloud networks: Anycasting, cooperation models
- Programmable core network test-bed for evaluating green protocols

Upcoming Challenges and Needs

- **The Internet is the Crucial Support System for the Global Cyber-Physical Infrastructure and Mobile Systems –**

- **Its Economic, Environmental and Technological Implications are Enormous**
  - **ICT Electricity > Electricity Consumption of Japan; CO2 Impact ~ Air Travel**
  - **UK ICT Electricity > Generation Capacity of Future Hinckley Point**
  - **Energy Consumed Mostly in the Wireless/Wired Interface + Wired**
- **The Ever Increasing Traffic Load, and the End to End Requirements of the IoT (connected cars, smart cities) require vast improvements in this Infrastructure viewed as a System which must be managed and renewed to optimise**
- **QoS and Delays,**
- **Energy Consumption and, Harvested Production and Storage**
- **Use of Virtuous Energies with Low CO2 impact**
- **Equipment Life-Cycle Cost and Energy**
- **Changes in Standards and Types of Equipment Selected**

Upcoming Challenges

This raises challenges in different related issues

- **Energy must be viewed as a combination of renewable, stored, and time of day more plentiful or less expensive energy sources being dynamically exercised for overall utility optimisation, including temporary energy storage and the self-energy production in terminal (IoT) devices**
- **The lifecycle of equipment and the optimum replacement of equipment and replacement by more energy efficient or cost efficient technologies is part of the medium-term optimisation**
- **Sharing of infrastructure including trade-offs between more local storage and more remote transmission must be considered**
- **The proper and changing balance between wired and wireless is a major architectural challenge**

Upcoming challenges and needs

- Control planes for such systems that provide convenient and transparent means of control will be needed
- Though SDN is an obvious way forward, this needs to be viewed outside the continuing or existing approaches such as Openflow, to consider the evolution of the control plane technologies to be open to new technologies including Optical
- The actual architectures of the control machines must also be considered to make sure that they are appropriately designed so that they do not introduce one more expensive layer which will consume an additional layer of excessive energy
- A big data approach will be needed to monitor these networks and to make sense of the data, so as to inject the knowledge gained from the data back into the control plane ad the decision processes

Possible Road Map

- Identify the core list of technical challenges
- Identify Sources & Technologies of Renewable Energy and Storage (Data & Energy) Compatible with User & Network Components
- Design an Overall Project Plan and Objectives
- Consult with an Industry Advisory Board and Area Experts
- Finalise the Project Plan and Use Cases
- Specify an Overall System Architecture and outline boundaries between wired and wireless, and the role of intermediate storage
- Build an Overall System Architecture
- Determine the form and details of Utility (Cost) Functions
- Design the on-line short and long term optimisation algorithms
- Test them on a set of Use Cases
- Valdate the results with demonstrations and industry validation

Role of Chist-ERA Support

- Identify cross-cutting themes
- Create Synergy throughout different EU funding Organisations for these themes
- Crystallise into a cogent and societally relevant research call
- Attract the top research talent and competences to converge on the themes and objectives
- Select the best proposals and teams
- Maintain momentum via coordination and encouragement
- Exhibit continuity in objectives and foster technology transfer
- Create annual industry days around specific project topics
- Influence wider scale European agencies and the European Commission, and Industry, to advance work on the challenges

Questions

Questions ?