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GEODES
(ITEA 2 – 07013)

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Improving power efficiency in mobile devices and communicating networks

The ITEA 2 GEODES project addressed power-consumption issues in complex distributed communications systems – such as handheld devices, smart phones, personal digital assistants and wireless sensor networks – from a global and coherent point of view, covering both internal nodes in a device and the network environment in which it has to function. The results are already being applied in several areas, including TV set-top boxes and video-surveillance systems, while the power-management strategy developed has been summarised in a freely available two-part handbook.

Today's mobile embedded devices offer ever more functionalities with ever greater connectivity as illustrated by advanced UMTS 3G mobile phones and personal digital assistants (PDAs). These devices now commonly integrate camera sensors for video and photo applications, while WiFi or Bluetooth wireless facilities are used to browse the web.

Such mobile devices are hugely dependent on their ability to manage limited battery capacities to reach reasonable individual autonomy. As a result of increasing complexity, power optimisation is no longer confined to the device itself but also needs to take into account its environment through the networks it accesses. The challenge is similar in large sensor networks, involving groups of communicating hardware/software nodes with heterogeneous capabilities – central processing unit, memory, etc.

MINIMISING ENERGY CONSUMPTIONS

GEODES focused on the requirement to minimise the energy consumption of future products for two reasons.

1. *Consumer awareness* of the need to focus on energy use for environmental reasons – driving product suppliers to invest in innovation which has a longer term impact on product efficiency, even if the unit cost is increased; and
2. *Device autonomy* which requires products to use less energy despite embedded devices now implementing many functions and with feature set an important selling point.

To fulfil the ever-rising need for new functionalities, new architectures offering more hardware power are required – including multi-cores and graphics processing units. However, while new hardware architectures are barely able to meet the performance demands, battery technology is clearly not evolving fast enough to address the energy problem. Thus, energy efficiency is becoming a differentiation factor and is motivating the design of low power embedded systems.

The interest in energy management is growing to cut power consumption, maximise battery life and decrease thermal dissipation. In addition, power management can have indirect impacts and valuable benefits to improve product characteristics. Indeed, working on energy-

efficient systems might help in designing lightweight systems and increasing component lifetimes.
Mobile devices are hugely dependent on their capability to manage limited battery capacities to achieve reasonable autonomy. With the variety of networking functionalities now available, power optimisation is no longer confined to the device itself, but should also embrace the network environment.

Applications which can take advantage of, or even become possible due to, lower power consumption include tele-healthcare and biomonitoring. These applications process data from wearable or portable platforms such as heart-rate monitors, activity sensors and glucose monitors. As these sensors and platforms should be wearable or portable, power consumption is critical. The ratio between available energy resources and consumed energy determines the limitations of the applications that can be deployed.

The slow evolution of battery technology has put the autonomy of embedded devices under pressure. In recent years, embedded processors have gone through an amazing evolution, illustrating the need for even better battery performance. Many attempts have been made to help reduce the growing gap; the most common technique is based on tailoring power consumption to performance.

OVERCOMING THE POWER/PERFORMANCE GAP

GEODES investigated a series of mechanisms for reducing power consumption of mobile devices, focusing on two specifically: those operating on the level of the individual nodes such as stand-by mechanisms, where nodes are switched to a standby mode to reduce their energy consumption; and those operating on the network level, such as transmit power control, where correct power levels need to be assigned to nodes in such a way that total power consumption is minimised but the whole network stays connected.

Project results will help overcome the power/performance gap for next generation communicating devices. Applying systems/software awareness to power issues is the key to bridge opposing evolution towards greater performance requirements and longer device autonomy. Coupling this awareness with a well balanced offline/inline power optimisation can bring major energy savings and eventually be considered itself as an enabling technology.

Major innovations in GEODES included:
- Power-aware protocols and applications;
- Power-aware components at operating-system level – new schedulers, new file system algorithms for data storage, new graphics drivers, quality of service (QoS) managers and power-monitoring facilities;
- Energy-efficient techniques for the network – new MAC algorithms, new routing algorithms, dynamic power transmission and dynamic node power adaptation to transmission rate;
- Middleware for QoS handling and node interoperability; and
- SystemC simulator for power estimation.

There is a massive potential for energy-efficient wireless-sensor networks (WSNs) and embedded systems. But seeing embedded systems as part of a more global picture could make market impact even broader. This is the vision of the Internet of Things (IoT) with machine-to-machine (M2M) connections. Indeed, WSNs and embedded systems can enrich the capabilities of M2M IoT systems such as: smart metering, smart grid and environmental monitoring; co-operative vehicle and transport infrastructures; and pay-as-you-drive car insurance.

Techniques developed in GEODES can help facilitate the deployment of M2M IoT systems featuring autonomy with efficient energy management and communications solutions for long-lasting operation. They also make possible advanced sensor- and actuator-based systems for safety and security, integrating networking capabilities and operating in harsh environments.

Markets where GEODES techniques can be applied include: wireless M2M connectivity through SIM-equipped devices; protection of critical infrastructure such as perimeter protection of oil pumping stations; environmental monitoring and fire-fighter protection; and airport protection with vast IP-based video surveillance networks.

OUTCOMES ALREADY BEING EXPLOITED

GEODES has achieved its goals and more with results and outcomes that have been measured and implemented. The power-management strategy has been summarised in a two-part public power-saving handbook written by the project and available for free consultation (http://geodes.ict.tuwien.ac.at/PowerSavingHandbook).

The approach developed is already being applied internally by project partners both to improve the autonomy of existing devices and as part of the design approach for new products. Key outcomes include orders-of-magnitude energy savings and lifetime extensions verified on multiple prototype demonstrators across diverse application domains.

Specific results include:
- Almost doubling of the autonomy of video-surveillance applications;
- A 100% extension in WSN lifetime, depending on size, structure and latency; and
- Up to 11% total energy consumption reduction for TV set-top boxes – in a 10 million product market, this would save some 62 GW of power a year. The environmental benefit is also helping to differentiate products in a mature market where all devices offer effectively the same set of functions.

MORE INFORMATION:
http://geodes.ict.tuwien.ac.at