Performance evaluation of DSP real-time operating systems in UMTS network

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Agenda

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Objectives of the thesis

- The main purpose of this study is to evaluate the performance of real-time operating systems for UMTS network DSPs
  - OSEck from Enea Embedded Technologies
  - DSP/BIOS from Texas Instruments
- Another objective is to find out the cumulative system-level effects of absolute RTOS performance differences
- The results are used to explore the feasibility of a possible RTOS swap

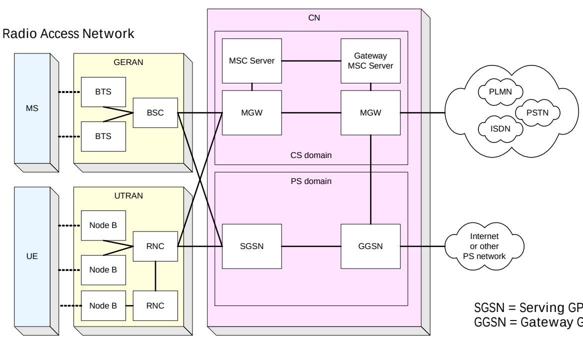
UMTS Release 4 network

- UMTS network is divided between User Equipment (UE), Radio Network (UTRAN) and Core Network (CN)
  - The core is divided into Circuit-Switched (CS) and Packet-Switched (PS) domains in Release 4
- There are many interfaces and computationally intensive features
- Signal processing capabilities need to be ubiquitous

GERAN = GSM EDGE Radio Access Network

MS = Mobile Station (GSM)
BTS = Base Transceiver Station
BSC = Base Station Controller

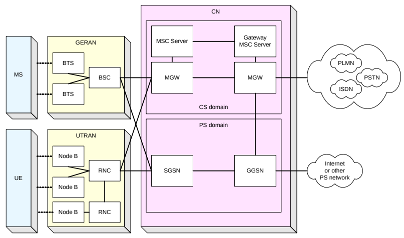
RNC = Radio Network Controller
MGW = Media Gateway
MSC = Mobile Switching Center



SGSN = Serving GPRS Support Node
GGSN = Gateway GPRS Support Node

Signal processing in UMTS network

- Coding and transcoding in UE, RAN and CN
  - Bandwidth adoption, error control and interworking
- Macro diversity combining in RAN
  - Soft handovers and improved channel performance
- Echo cancellation in CN
  - Improved voice quality
- Packet handling in UE, RAN and CN
  - High-speed PS data communication
- Ciphering in UE and RAN
  - Enforced communication privacy
- Modems in CN
  - Legacy data connections



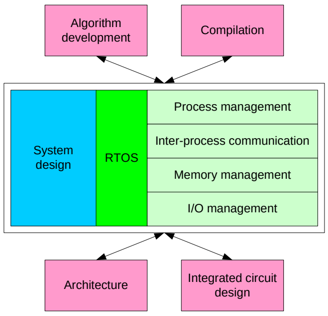
A single network element may well contain over two thousand DSPs!

DSP features and trends

- Fast multiplication operations and multiple execution units with efficient memory access buses and I/O interfaces
- Relatively cheap processing units with low power consumption
  - Performance/price and performance/consumed power are relevant metrics for typical applications in the embedded world
- The amount of fast internal code and data memories are typically very limited
  - Non-critical code and data is assigned to external memory
- Because of operational limits for power consumption, DSP clock frequencies can't simply be raised like in general-purpose processors
  - Potential application-specific accelerators will enhance the performance of certain tasks such as ciphering
  - Multicore DSPs will bring improved performance with both low power consumption and cost

RTOS characteristics

- Provides an abstraction and interface of common system services for real-time applications
  - Leads to more simple and reliable applications
- In essence a framework of
  - System resource management and scheduling
  - Inter-process communication
  - Interrupts
  - Memory management
  - Error handling
- Real-time domain calls for
  - Deterministic behavior
  - Fast response times
- Embedded applications require also
  - Small size
  - Scalability



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OSEck vs. DSP/BIOS

- OSEck
  - 5th largest commercial or third-party RTOS
  - The whole OSE product family is available for many DSPs and GPPs
  - License required
  - Telecom-oriented product with high performance and somewhat optimized feature set
  - Enea's core competence and business is in the RTOS world
- DSP/BIOS
  - RTOS market leader
  - Available only for TI DSPs
  - Royalty-free
  - More general-purpose product with heavy structure and a number of OS features – yet some other important features are still missing
  - Only complements TI's total product offering

GPP = General-Purpose Processor

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RTOS performance criteria

- Memory consumption
  - Kernel size
  - Run-time object sizes
- System call performance
  - Memory operations
  - Inter-process communication
  - SW and HW interrupts
- System-level performance
  - Total memory consumption in system
  - System performance and capabilities
- Other issues such as cost, API functionality, ease of use and debugging capabilities are ignored in this comparison

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Performance testing methods

- MIPS, MOPS, MACS etc. are ill suited for giving detailed and comparable performance results
- Memory consumption measurement
  - Static requirements highlight the basic picture
  - Run-time allocations need to be monitored dynamically
- Processing cycle consumption measurement
  - Run-time profiling for defined code areas, e.g. functions
- Application benchmarking
  - Total memory consumption
  - Application-specific metrics, e.g. data throughput or perceived latency
- Together these three methods complement each other well and pinpoint the possible bottlenecks

MIPS = Million Instructions Per Second
MOPS = Million Operations Per Second
MACS = Multiply-Accumulates per Second

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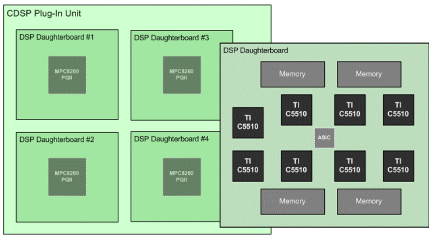
Test system

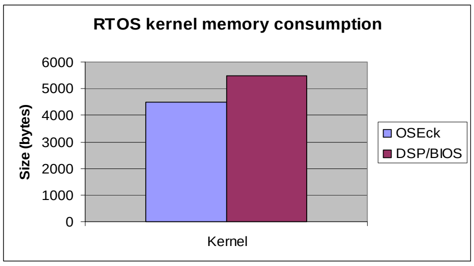
- Actual 3GPP Release 4 –compliant RNC/MGW hardware and relevant platform software
- DSP plug-in units with 4 Freescale PowerQUICC II communications processors, each controlling 8 independent TI TMS320VC5510 DSPs
  - 32 DSPs / plug-in unit; 8 MB external SDRAM memory / DSP

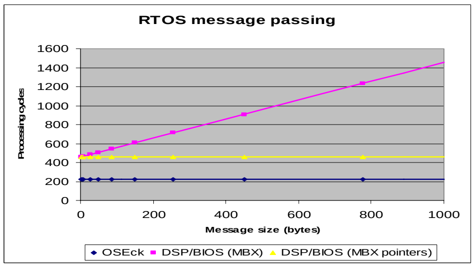


- An I/O-oriented test application with RNC-like behavior for measuring maximum data throughput in the system
- OSEck R3.2.3 and DSP/BIOS 5.0

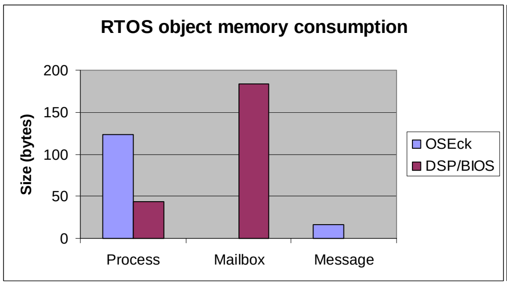
RTOS performance results

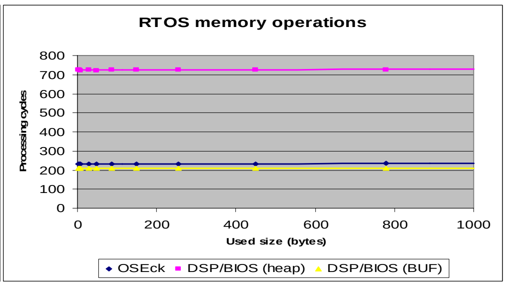
- DSP/BIOS kernel is ~20% larger than OSEck kernel
  - The absolute difference is however small and still quite tolerable
- With RTOS objects the differences depend on use cases, but DSP/BIOS seems to require more memory anyway
- OSEck provides all-round good performance with its memory operations, while DSP/BIOS is slow with heaps and fast with fixed-size buffers
- Message passing shows the largest differences, especially if DSP/BIOS mailboxes are used to pass entire messages
- HW interrupts perform at the same level in both DSP/BIOS and OSEck, but SW interrupts are 40% faster with OSEck

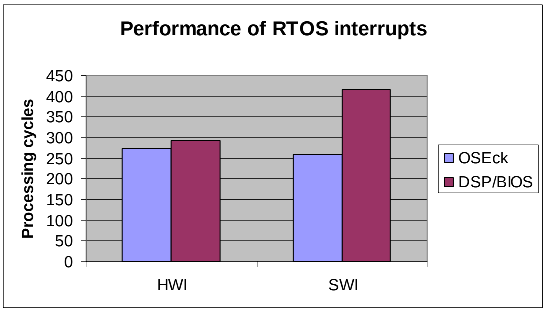




RTOS performance results, contd.

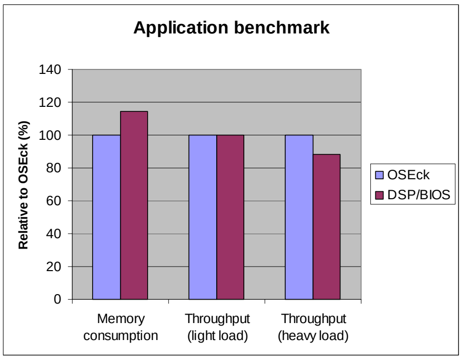






Application benchmark results

- System-level memory consumption is increased ~15% with DSP/BIOS
  - Basically in line with the RTOS-level measurements, but still somewhat more than expected
  - In absolute numbers the difference is starting to become significant
- Throughput remains practically constant if there is only light load
  - The DSP has enough idle time to accommodate RTOS performance differences
- Under heavy load the average throughput with DSP/BIOS suffers a loss of ~12% !!!
  - Statistically significant jitter was also present with DSP/BIOS – calculated standard deviation in consecutive tests was ~5% !!!



RTOS performance scorecard

- The weightings and grades are subjective and reflect the current requirements of UMTS network elements and applications
- DSP/BIOS is in all cases inferior to OSEck
  - System call performance seems to be the main bottleneck in DSP/BIOS
  - At system-level the differences are evened out, but not enough
- However, the DSP/BIOS performance and results are still in adequate range for a number of purposes
  - DSP/BIOS is OK, but OSEck is better at least in terms of speed and size

		Grades (4-10)	
RTOS property	*Weight*	*OSEck*	*DSP/BIOS*
Kernel size	15 %	9,5	9
Object sizes	5 %	10	9,5
Memory operations	5 %	9	7,5
Message passing	15 %	9	6
Interrupts	10 %	8,5	8
Application size	20 %	9	8
Application throughput	30 %	9	7,5
	100 %	**9,1**	**7,8**

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Conclusions

- RTOS performance may have a significant effect on end-system capacity
- DSP/BIOS is considerably slower than OSEck
  - With typical RTOS system calls the increase in processing cycle consumption is 20% - 200%
  - Application throughput is reduced 10% - 15%
  - DSP/BIOS does not always behave deterministically
- DSP/BIOS requires a larger memory footprint than OSEck
  - The plain kernel-level increase is 20%
  - Increase for a whole application is 15%
- Currently it is not technically reasonable to use DSP/BIOS instead of OSEck in the studied case
- Benchmarking effort will be continued and updated with upcoming new hardware and RTOS variants

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