Functional Programming^{XP}

The Industrial Experience

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- M.Sc. – Comenius University, Bratislava
- Ph.D. – Chalmers
- Post-doc – Chalmers
- System Designer – Dfind IT
  - On assignment for Ericsson
  - Operations & Maintenance Subsystem

The Chalmers Years

- **Research in static analysis of concurrent programming languages**
  - Type systems
  - Protocol analysis

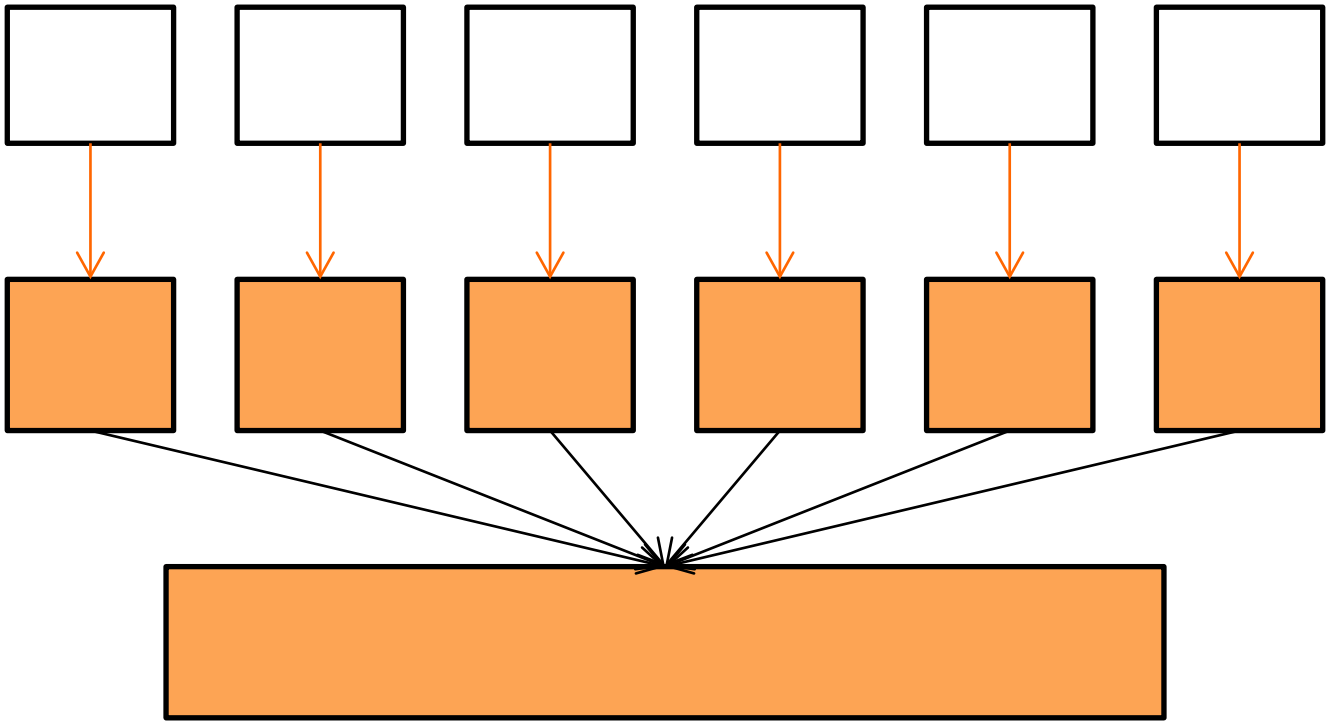
- **Main course responsible**
  - Concurrent Programming Course – TDA381
  - Developed the course between 2005 and 2010

The Language & Paradigm Nerd

- **Language skills**
  - Basic
  - Pascal
  - C/C++
  - Scheme
  - SmallTalk
  - Java
  - JR (MPD)
  - Haskell
  - Erlang
  - Ocaml
  - LaTeX
  - VAX assembler
  - Trilogy
  - Ada
  - Agda

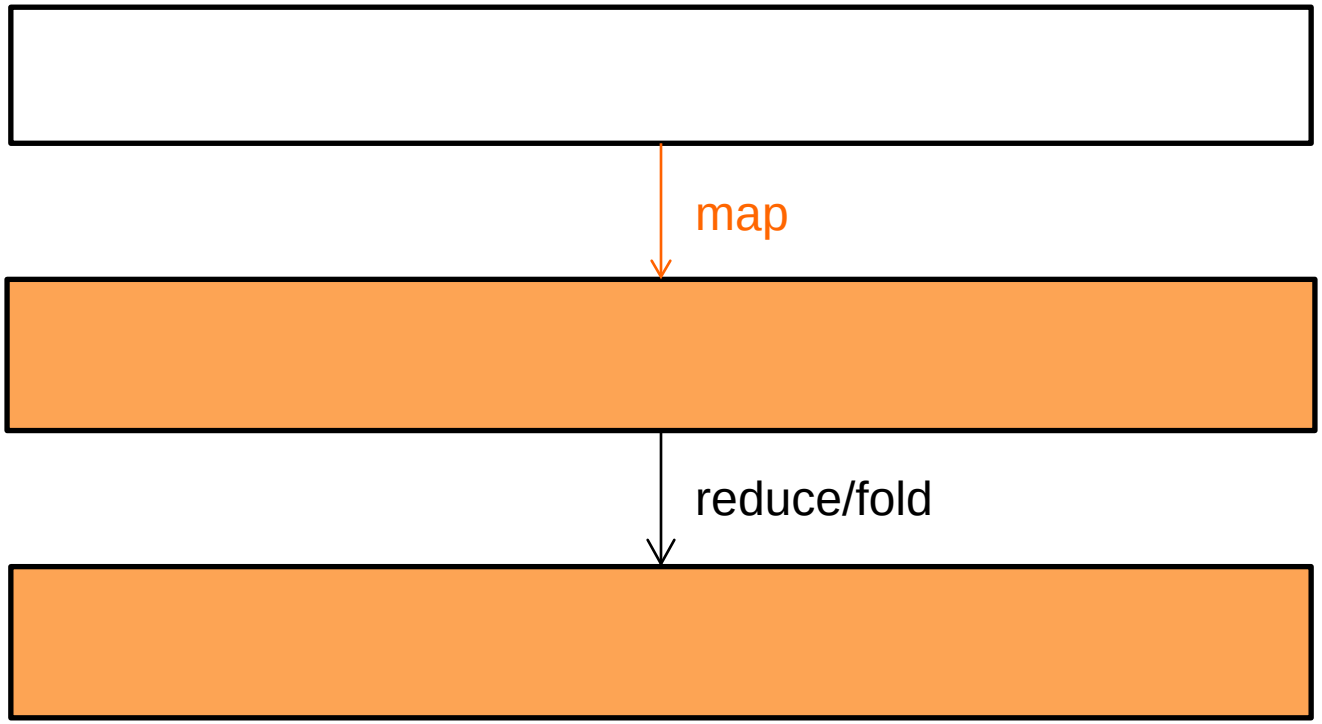
What is Programming?

- Manipulation of Structures



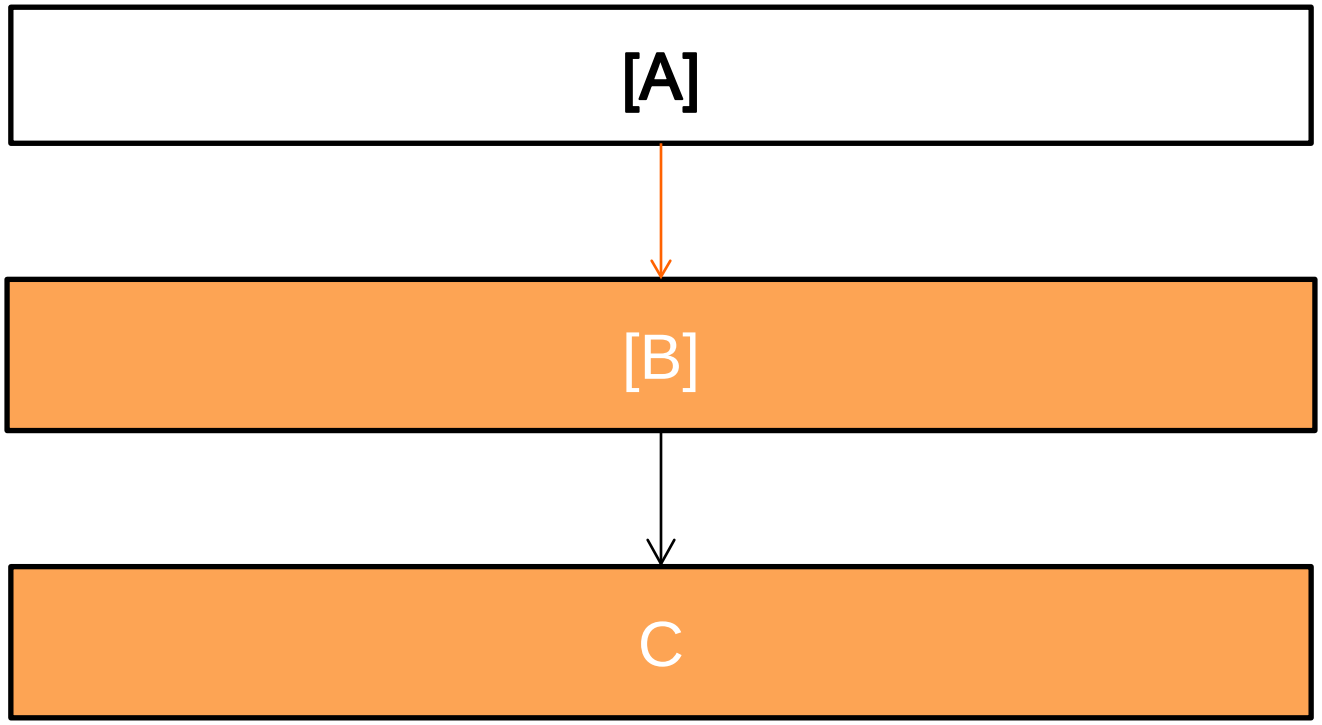
Compositions

- Functions



Structures

- Types



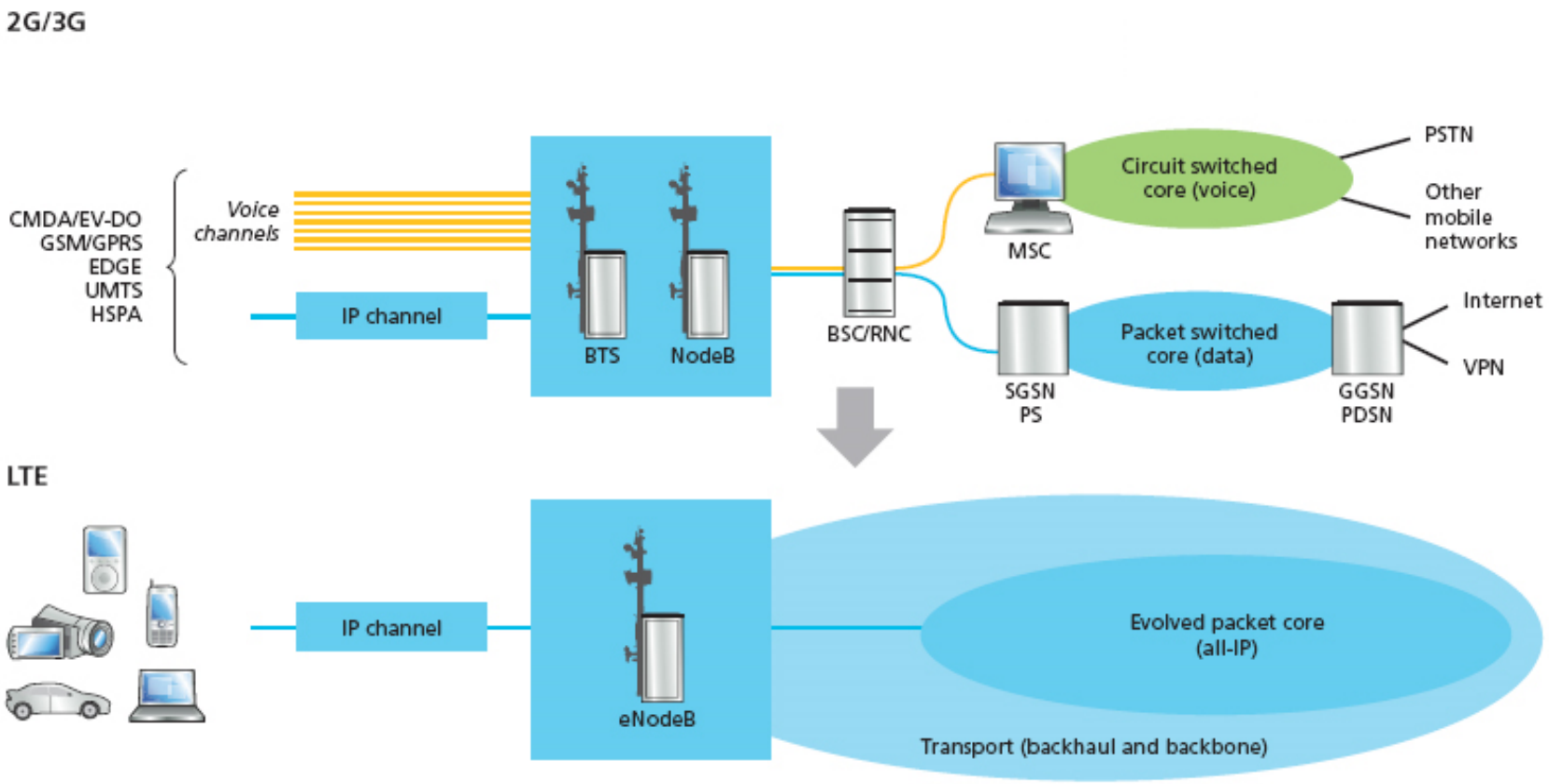
My Favourite Slide

The Message from this Course

- Should you forget everything from this course, please, remember at least this saying:

> Use the right tool for the job.

Mobile Telecom Network



Packet Core Network

- 3GPP
  - Defines standards (mostly protocols)
  - Interoperability is essential
- SGSN-MME
  - Servicing GPRS Support Node (2G/3G)
  - Mobility Management Entity (4G)
  - Control signalling
    - Admission control, Authentication
    - Mobility, roaming
  - Payload transport (not in 4G)

SGSN-MME MkVI

- 3 sub-racks
- 21 blades (2+19)
- 2 core PowerPC
- *~ 114 simultaneously running processes*

- Backplane: 1Gbps

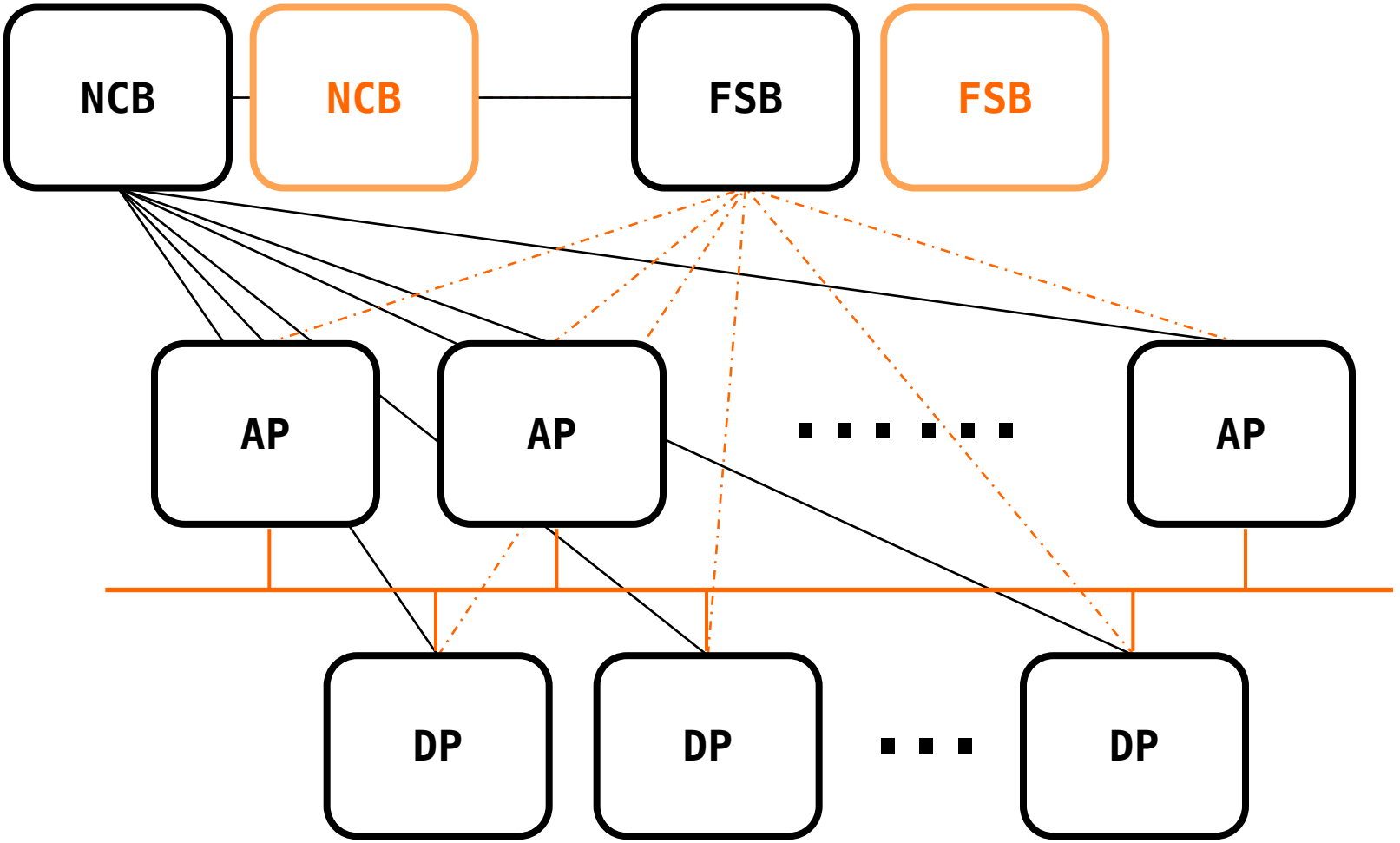
- Capacity: 3MSAU

Dfind IT

SGSN-MME MkVIII

- 3 sub-racks
- 14 blades (2+12)
- 6 core Intel x86
  - 12 SMT threads total
- *~ 432 simultaneously running processes*
- Backplane: 1 or 10Gbps
- Capacity: 10MSAU

SGSN-MME – Architecture Sketch



SGSN-MME – Use The Right Tool

- Control Plane
  - Erlang
    - concurrency
    - distribution
    - fault-tolerance
  - DSL
    - frameworks for protocol implementation
- User Plane
  - C
  - time-critical

Erlang – The Functional Advantage

- Protocol Programming
  - 3GPP standards
  - Domain experts not software engineers

- DSL
  - A “library” of abstractions
    - Possible in any language
    - Often easier in a functional language
  - A set of combinator “glues”
    - Considerably more powerful in a functional language

Typical Concurrency Patterns

- **One mobile – one process (replicated worker)**
  - Isolation
  - Synchronisation only with resources
- **Central resources**
  - Resource allocator
  - Master/coordinator – slave/worker
  - Transaction handler

Distribution

- **One mobile – one process**
  - Evenly distribute all phones over all blades
  - Replicate data for fault-tolerance
- **Central resources**
  - Run on the master-blade
  - Replicate to all the slaves
  - Can we survive without a master?

Fault-tolerance

- **SGSN-MME requirement: 99.999% availability**

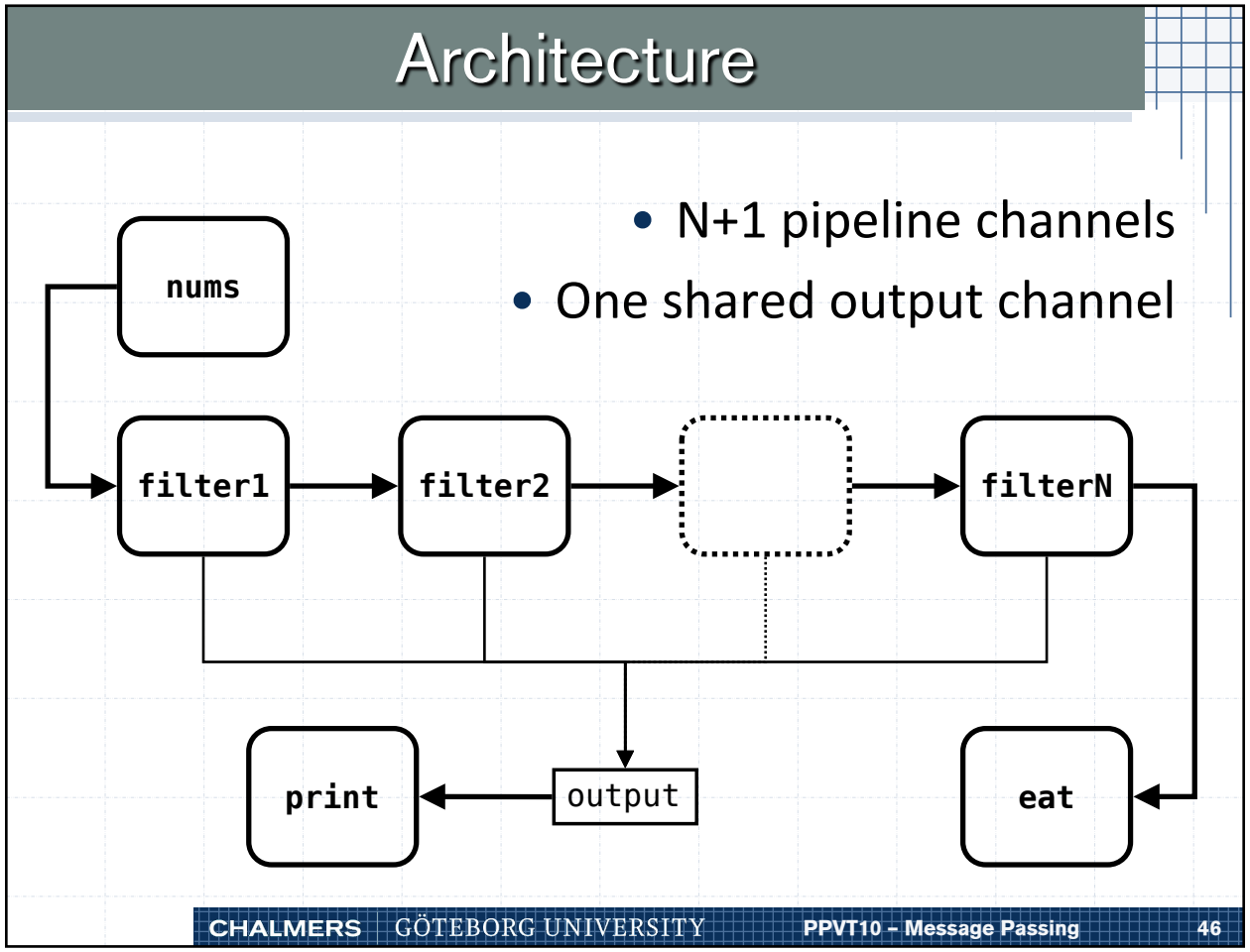
- **Hardware**
  - Faulty blades are automatically taken out of service
  - Mobile phones redistributed
- **Software**
  - Fail fast – offensive programming
  - Recovery strategy

Fault-tolerance – Software

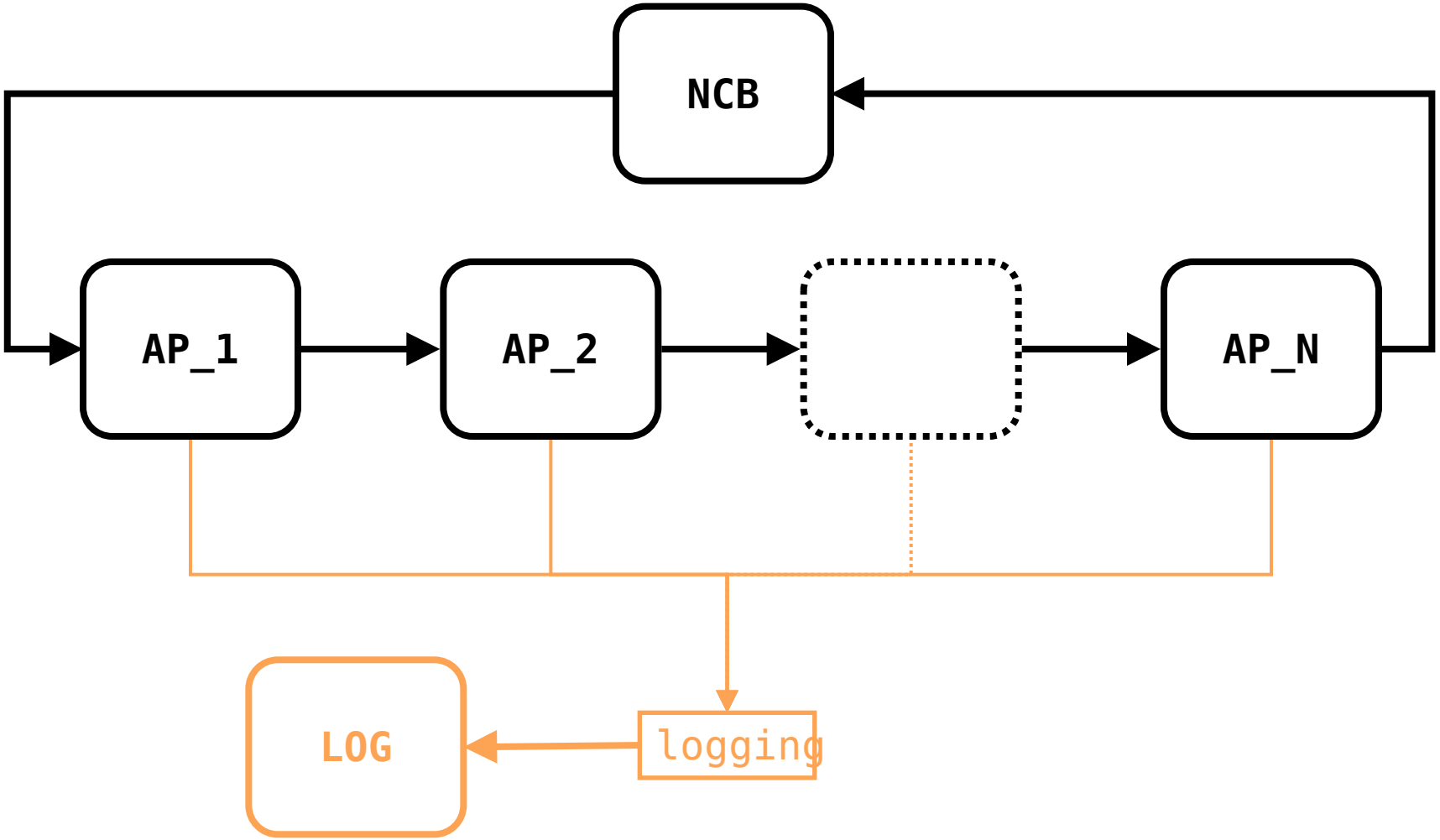
- **Phone process crash should never affect others**
  - Automatic memory handling
  - Process monitoring

- **Recovery Strategy – escalate**
  - Restart the phone process
  - Restart the whole blade
  - Restart the whole node

Sieve of Eratosthenes



Pipeline of Processes



Haskell Patterns – Monads

- Good
  - Keeps pure and side-effecting computations apart
    - Good separation of concerns
    - Improved compositionality
    - Possible performance gain
  - Gather writes together and write to DB once – amortise the cost of transactions:
    - 1 item write costs 10
    - 10 items write is not 100 but only 20!

Haskell Patterns – Monads

- Bad
  - In rapid prototyping it can present a big hurdle to jump over
  - So, it is good that Erlang does not have static types

OO-Design Patterns

- **Factory method**
  - Improve memory sharing
- **Object pool**
  - Bounded parallelisation of algorithms – thread pool
  - Overload protection

What they do not teach you

- Software lives long
  - Especially telecom systems (decades)
  - Banking systems live even longer (think COBOL)
- People change
- Organisations change
- Hardware changes
- Requirements change
- Documentation often does not change

Software Maintenance

- **The developer's challenge**
  - Write simple (readable) and efficient code:
    1. Write a straightforward and working solution first
    2. Optimise later (or even better skip this step)
- **Think smart but do not over-optimise**
  - Optimisations complicate maintenance
- **The code is often the only reliable document**
  - Types can be very good documentation

Synthesis and Analysis

- **Emphasis on synthesis in education**
  - Software development from scratch
- **Industrial systems often have a legacy**
  - Software development by further iteration
    - Refactoring
    - Code review
    - Software maintenance
  - Need for both analytical and synthesizing thinking

Synthesis and Analysis

- **Roughly 30% of manpower is spent on testing**
  - Analytical work
  - Do you like to break a system?

- **But testing can also be “synthesizing”**
  - Testing frameworks
    - Quickcheck
    - SGSN-MME has its own
  - Would you like to formally prove the system correct?

Erlang in Practice – Pros

- **Well suited for**
  - Control handling of telecom traffic
  - Application layer (OSI model) applications
    - Web servers, etc.
  - Domain Specific Language – framework
    - Test scripting
- **Reasonably high-level (as compared to for example C)**
  - Good for software maintenance

Erlang in Practice – Pros

- **Dynamic typing**
  - Aids rapid prototyping
- **OTP – includes useful building blocks**
  - Supervisor
  - Generic server
  - Finite state machine

Erlang in Practice – Cons

- **Hard to find good Erlang programmers (?)**
  - Management b.....t
  - Long live Chalmers
- **A bit too low-level language**
  - Given current HW limitations one must sometimes optimise to the point where the code is not portable (with the same performance)
  - Raise the abstraction and provide a customisable compiler, VM (Elixir?)

Erlang in Practice – Cons

- **Where is the type system?**
  - A static type system of Haskell-nature would probably be a hindrance
  - But good static analysis tools are desperately needed
  - Types are an excellent form of documentation

More Than True

Sayings

- The greatest performance improvement of all is when a system goes from not-working to working
- The only thing worse than a problem that happens all the time is a problem that doesn't happen all the time

Functional Programming^{XP}

- **The industrial experience**
  - It is more difficult that you expect, but
    - Usually not in complexity but size
  - Good methodical approach helps
  - Lateral thinking is an asset
    - Learn many programming paradigms
    - Learn many programming languages