Computer Graphik
Universität
des Saarlandes

Network-Integrated Multimedia Middleware

KDE aKademy 2004

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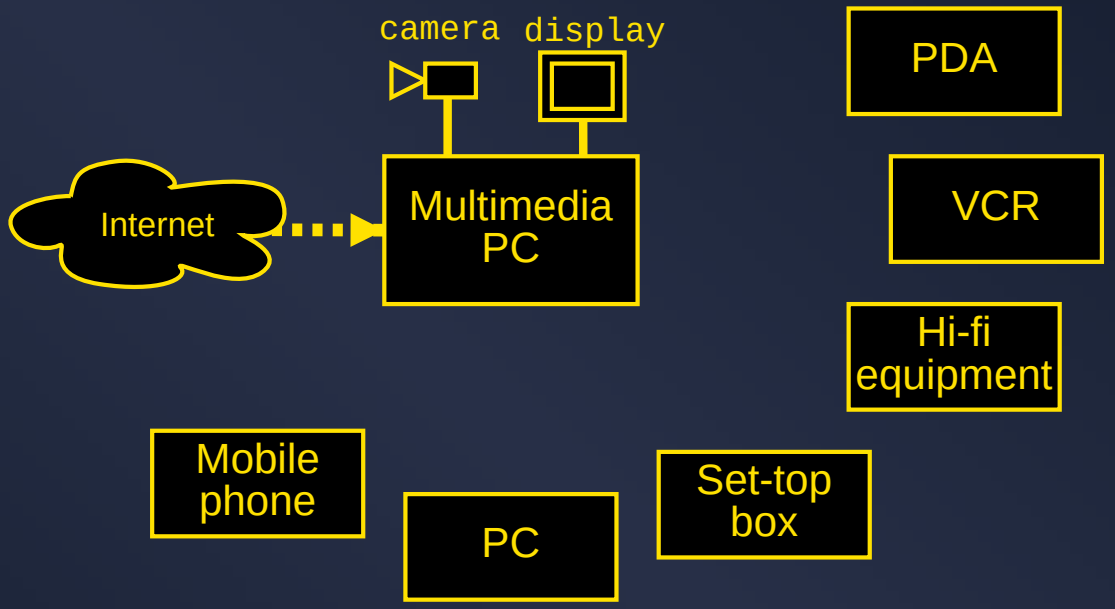
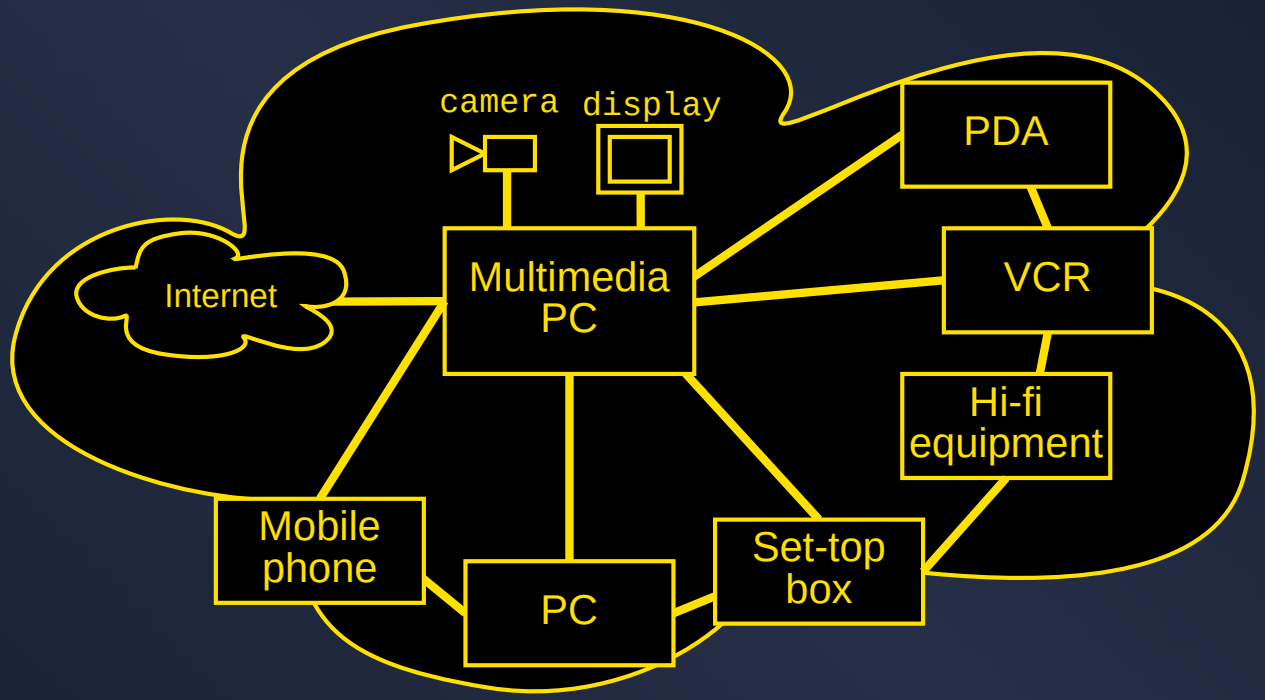
Motivation



- PC-centric approach (back in 2000, today?)
  - Stand-alone multimedia-PC
  - Streaming predefined content from the Internet
  - Many other multimedia devices

  $\Rightarrow$ Unexploited networking capabilities

Motivation

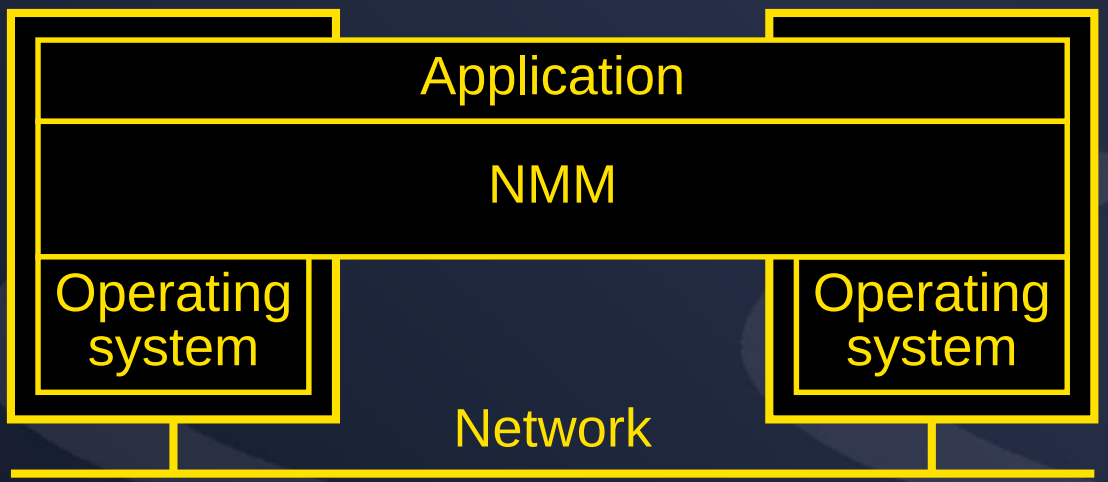


⇒ Network-Integrated Multimedia Middleware (NMM)

- GNU/Linux (x86/ARM), LGPL/GPL, C++
- http://www.networkmultimedia.org

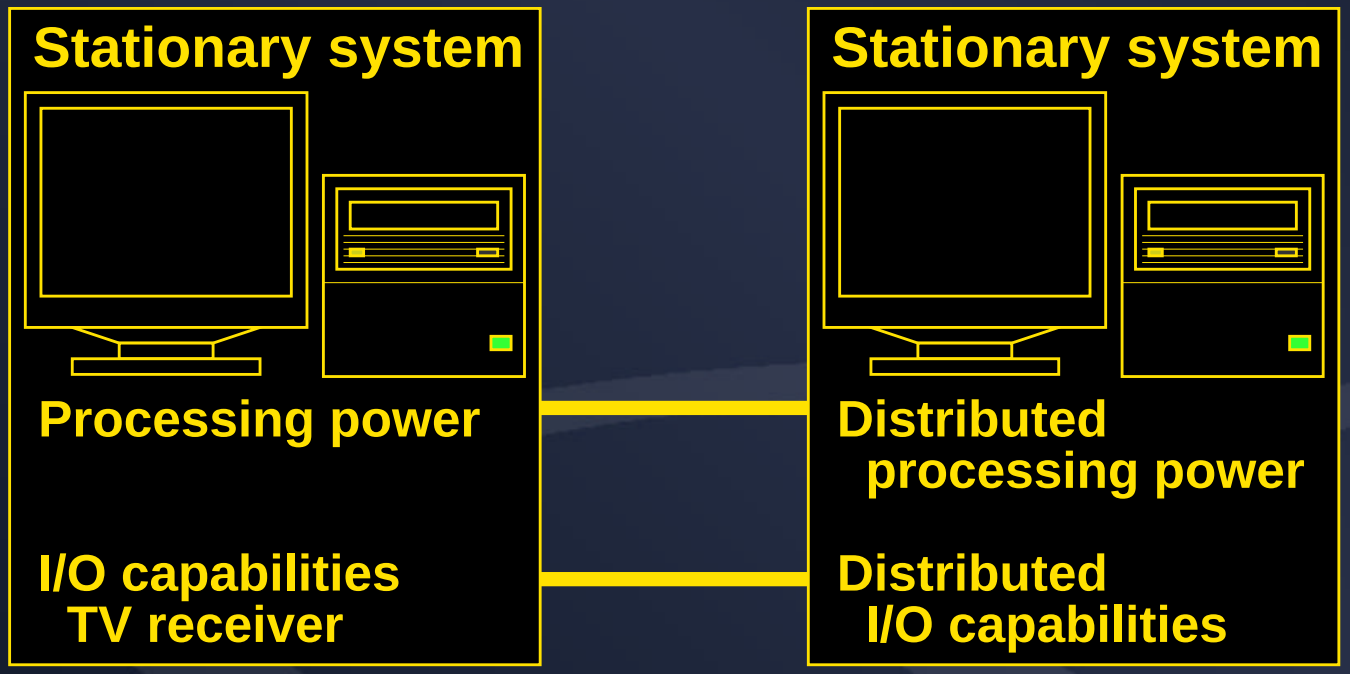
NMM

- Network-Integrated
  - Extend cooperation and control to network
- Multimedia (for GNU/Linux)
  - Uniform access to available drivers and libraries
- Middleware
  - Layer between applications and distributed systems



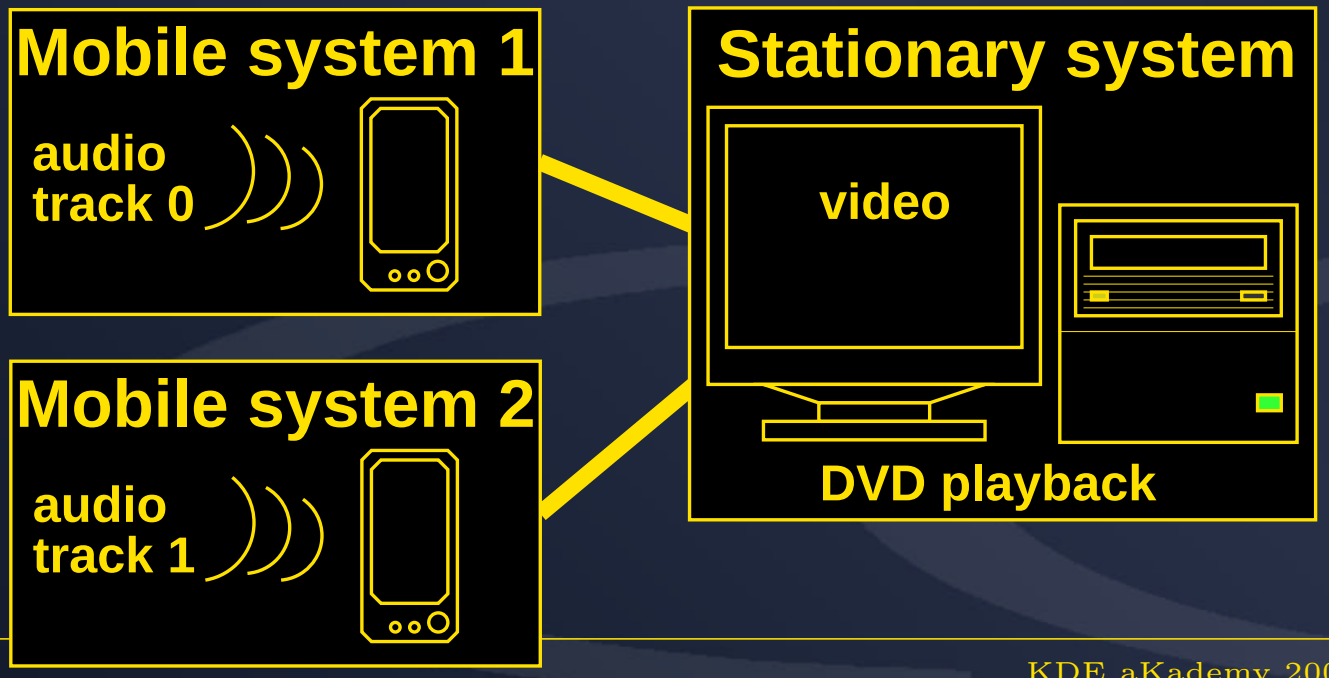
Application Scenarios

- Access distributed resources
  - Distributed transcoding
  - Watch TV using remote TV receiver
  - Control remote TV receiver



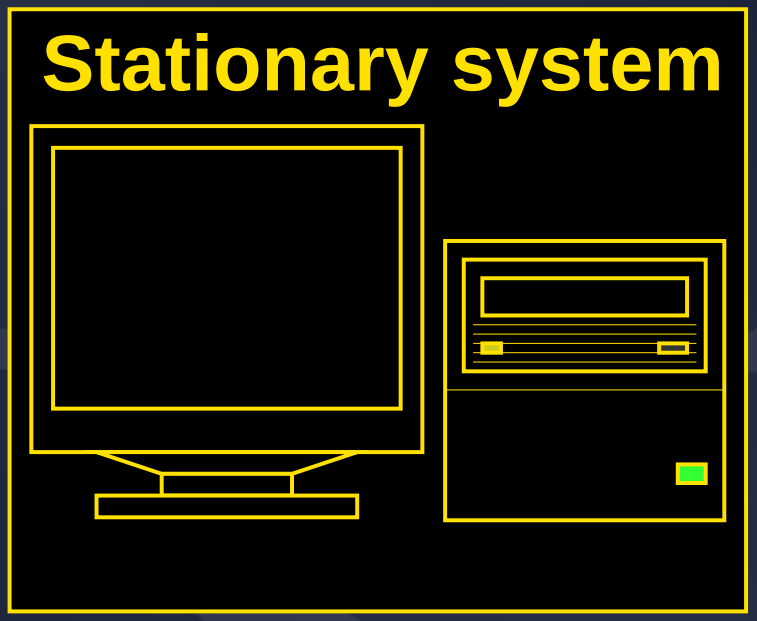
Collaborative Scenarios

- Number of users simultaneously enjoys the same (or similar) content using different devices
- "Drive-in cinema"
  - Watch video of DVD on large screen
  - Synchronized playback on different PDAs



Dynamic Scenarios

- User and device mobility
- Use capabilities of surrounding environment
- Handover of media playback
  - E.g. use high-fidelity audio output



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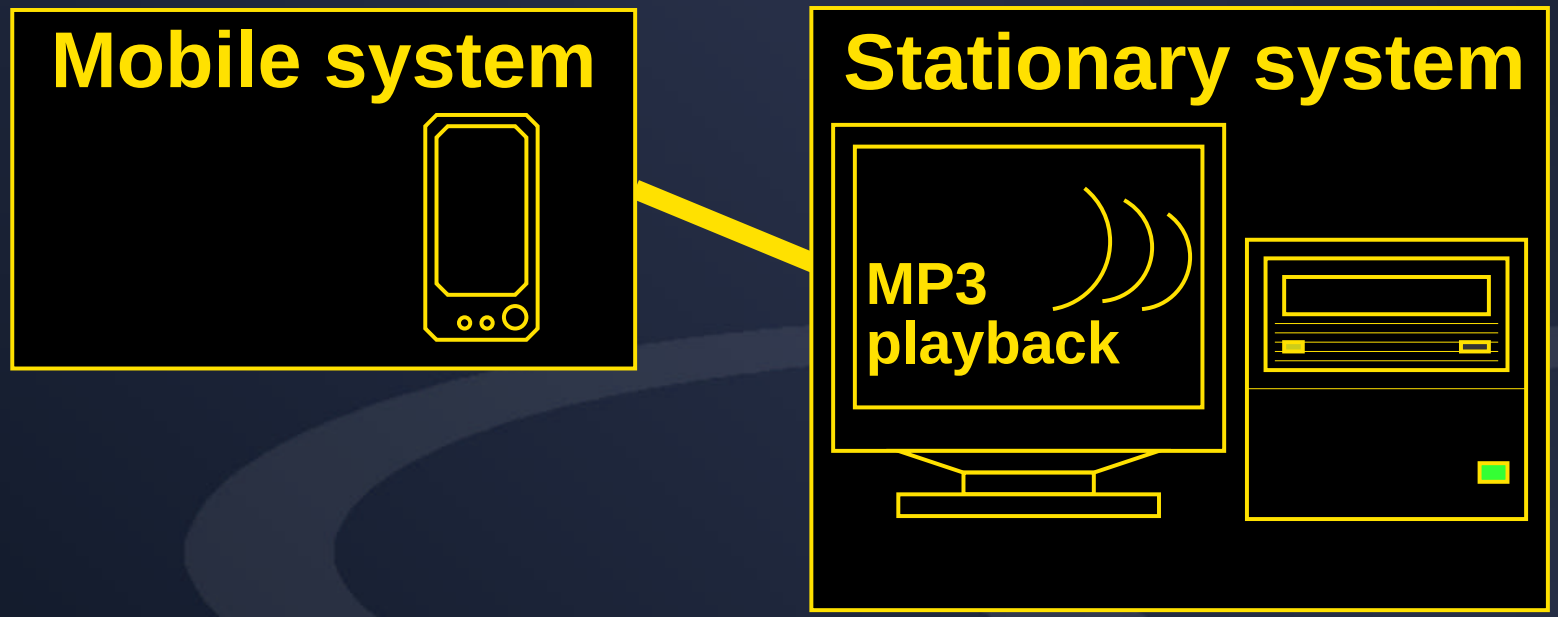

Beyond Client/Server

- Traditional client/server streaming ⇒ Black-box
  - Locate server? Activate server? Provided functionality? Connection setup? Streamed data format? Control server, e.g. switch the TV channel? Complex application scenarios, e.g. transcode content? Distribute workload? Synchronization? Shared applications?

Beyond Client/Server

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⇒ It's not a question of "if" – it's a question of "how"

⇒ Generally solve challenges within middleware

⇒ Provide suitable abstractions and programming model

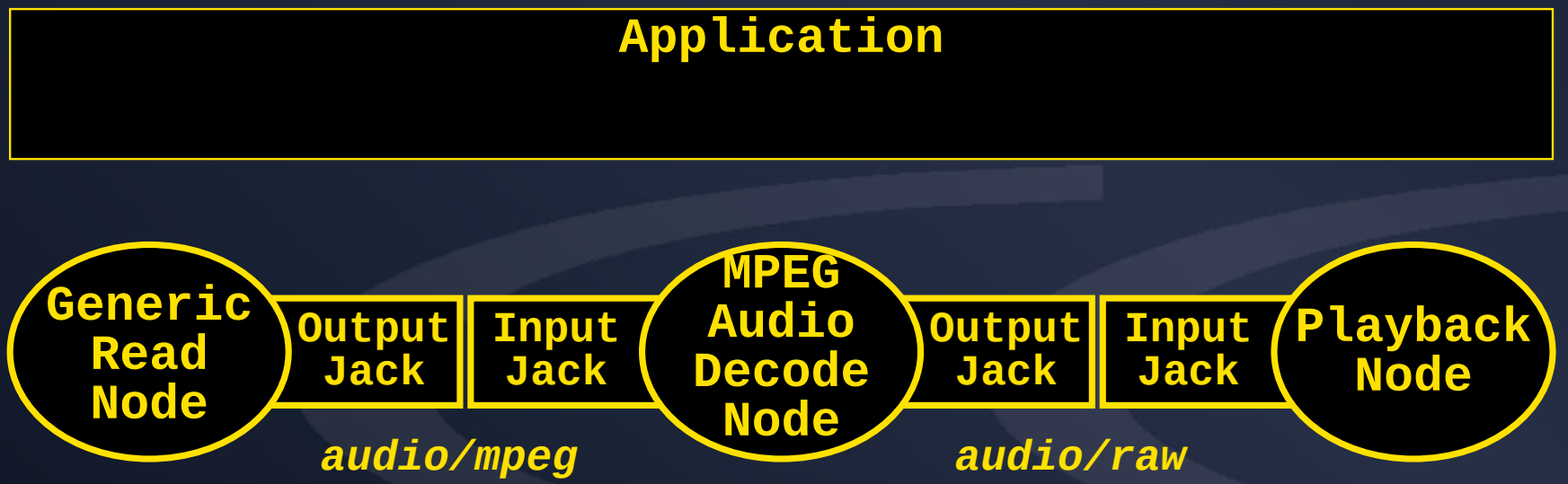
⇒ Easy, efficient development of distributed applications

Overview

- Motivation
- Architecture of NMM
- Developing plug-ins for NMM
- Basic middleware services
  - Registry service, Synchronization, GraphBuilder
- Distributed multimedia application
  - helloworld, clic, Multimedia-Box, ...
- Advanced Middleware Services
  - Application sharing, seamless handover
- Summary, future work & discussion

Flow Graph

- Nodes as smallest processing unit
- Jacks to connect nodes
- Formats to type connections
- Interfaces to control objects
- Messages to forward media data or control information



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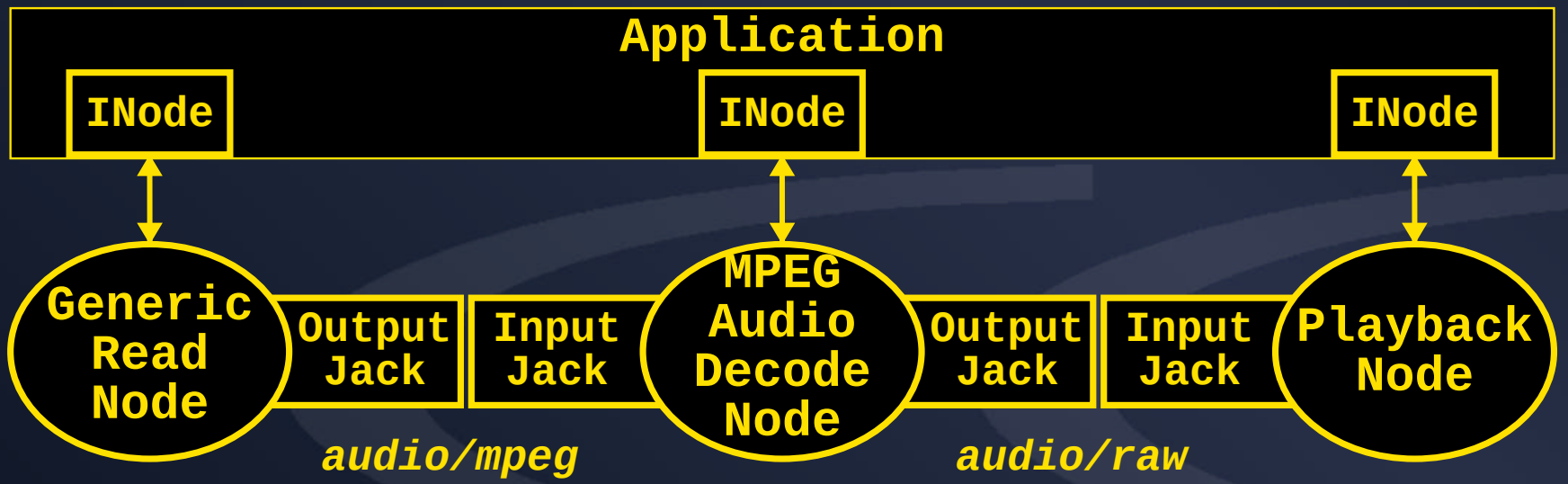

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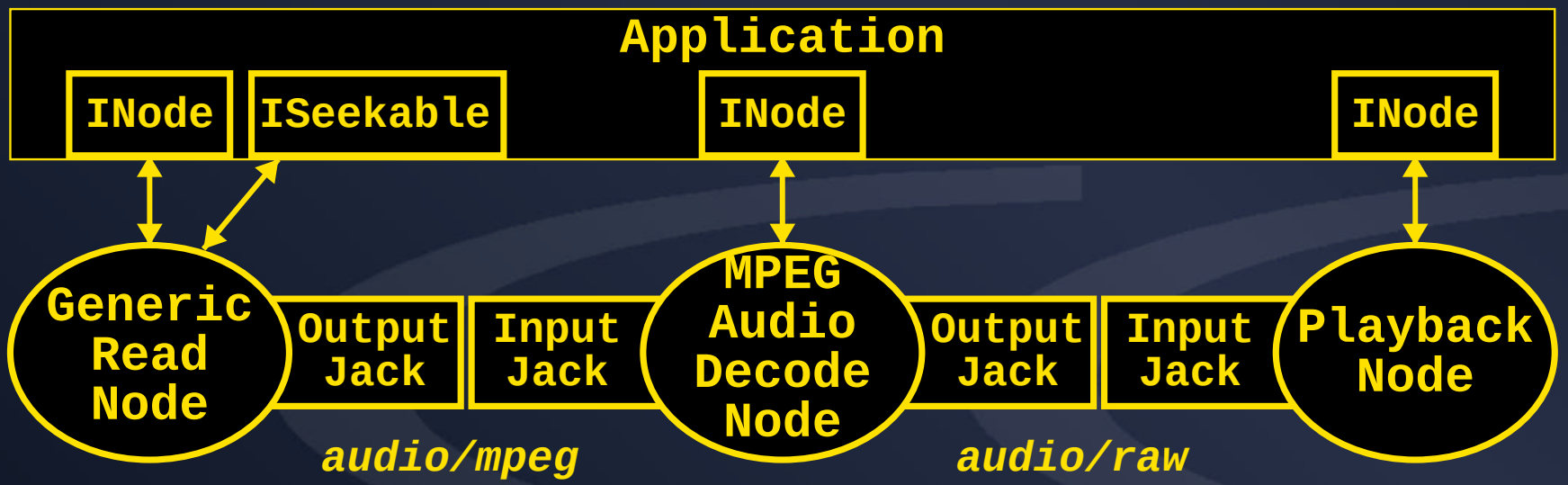

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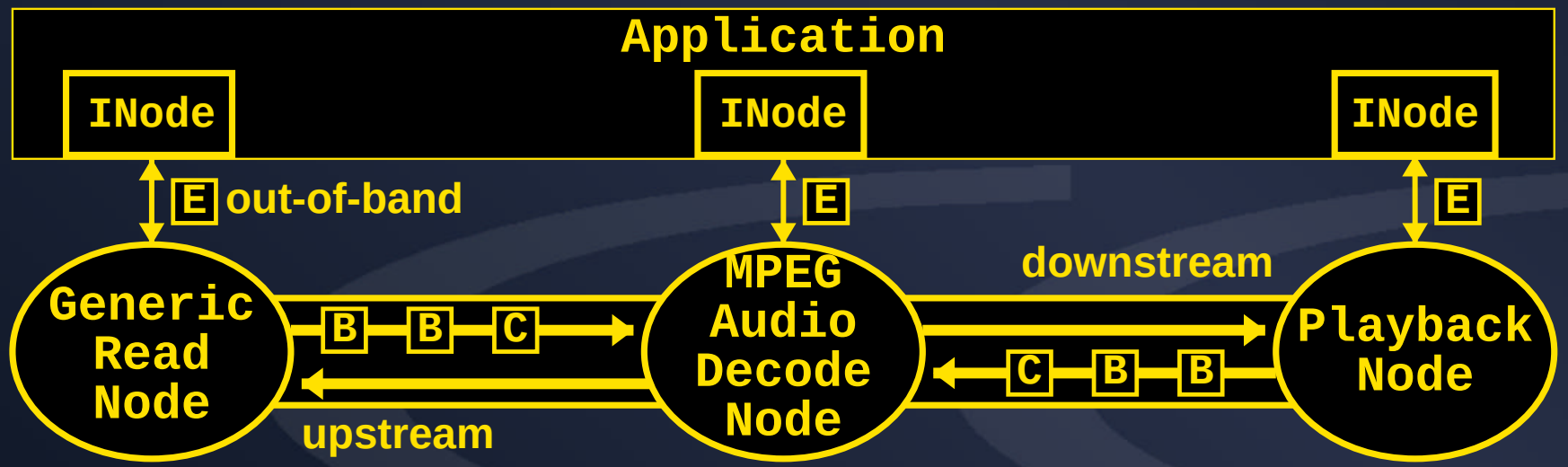
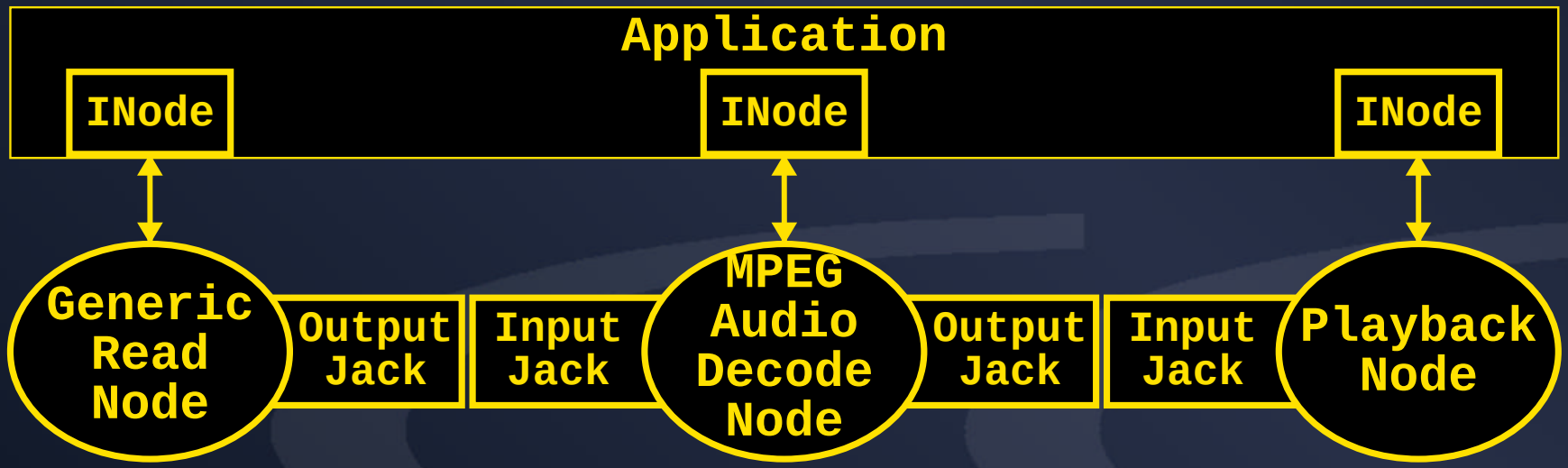


Messaging System

- Message
  - Header information such as timestamps
- Buffer
  - Multimedia data
  - Efficiently managed by buffer pools
- Composite event (CEvent)
  - Stores list of events
- Event
  - Key, list of values, return value, exception
  - Represents single method call for dispatcher
  - Both, out-of-band and instream interaction

Flow Graph

- NMM flow graphs are distributed
- Local and remote nodes can be controlled and integrated into a common flow graph
- Transparent for developers, no overhead for all co-located parts of flow graph



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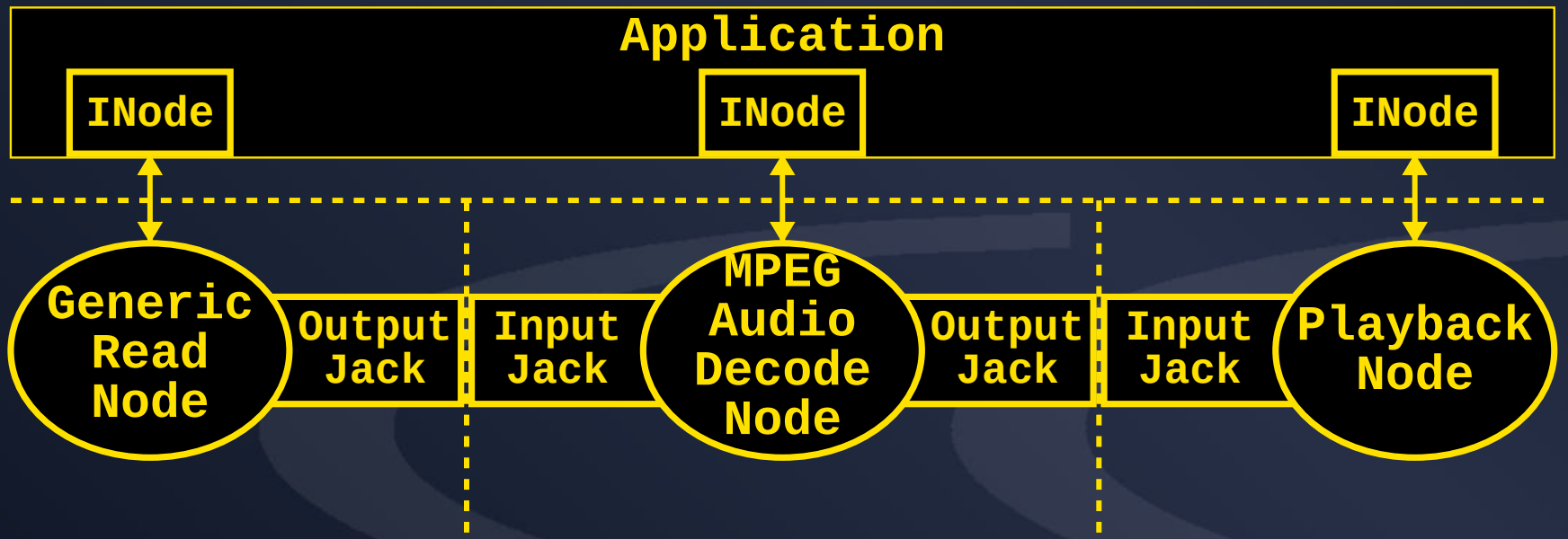


Interfaces

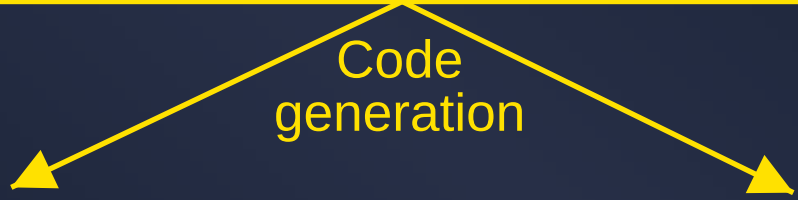
- NMM Interface Definition Language (NMM IDL)
  - Similar to CORBA IDL
  - Interface class and implementation skeleton
  - Supports inheritance, exceptions, arbitrary data types, state machine, ...
  - Both, out-of-band and instream interaction

Interfaces

IFileHandler.idl

```
module NMM {
  interface IFileHandler {
    void setFilename(in string name);

    Result endTrack() instream;
  };
}
```



IFileHandler

```
+setFilename(const string&): void
+endTrack(): Result
+create_endTrack(): Event*
```

IFileHandlerImpl

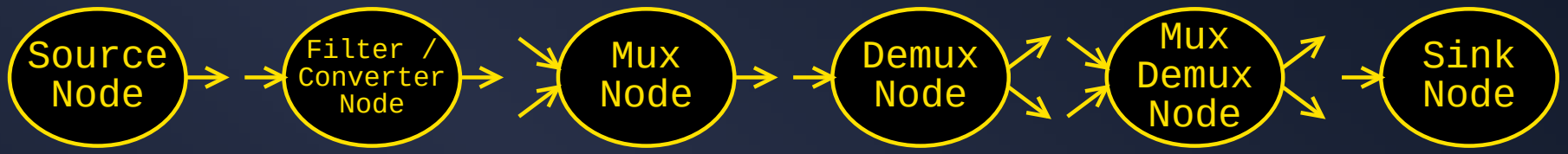
```
+setFilename(const string&): void
+endTrack(): Result
```

ConcretePluginNode

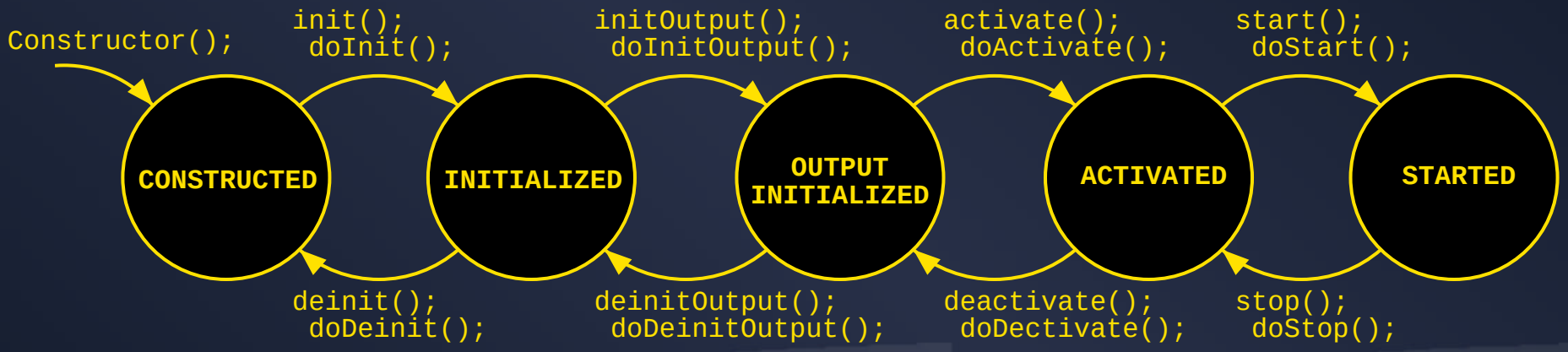
```
+setFilename(const string&): void
+endTrack(): Result
```

Nodes

- Different types of nodes & generic base classes



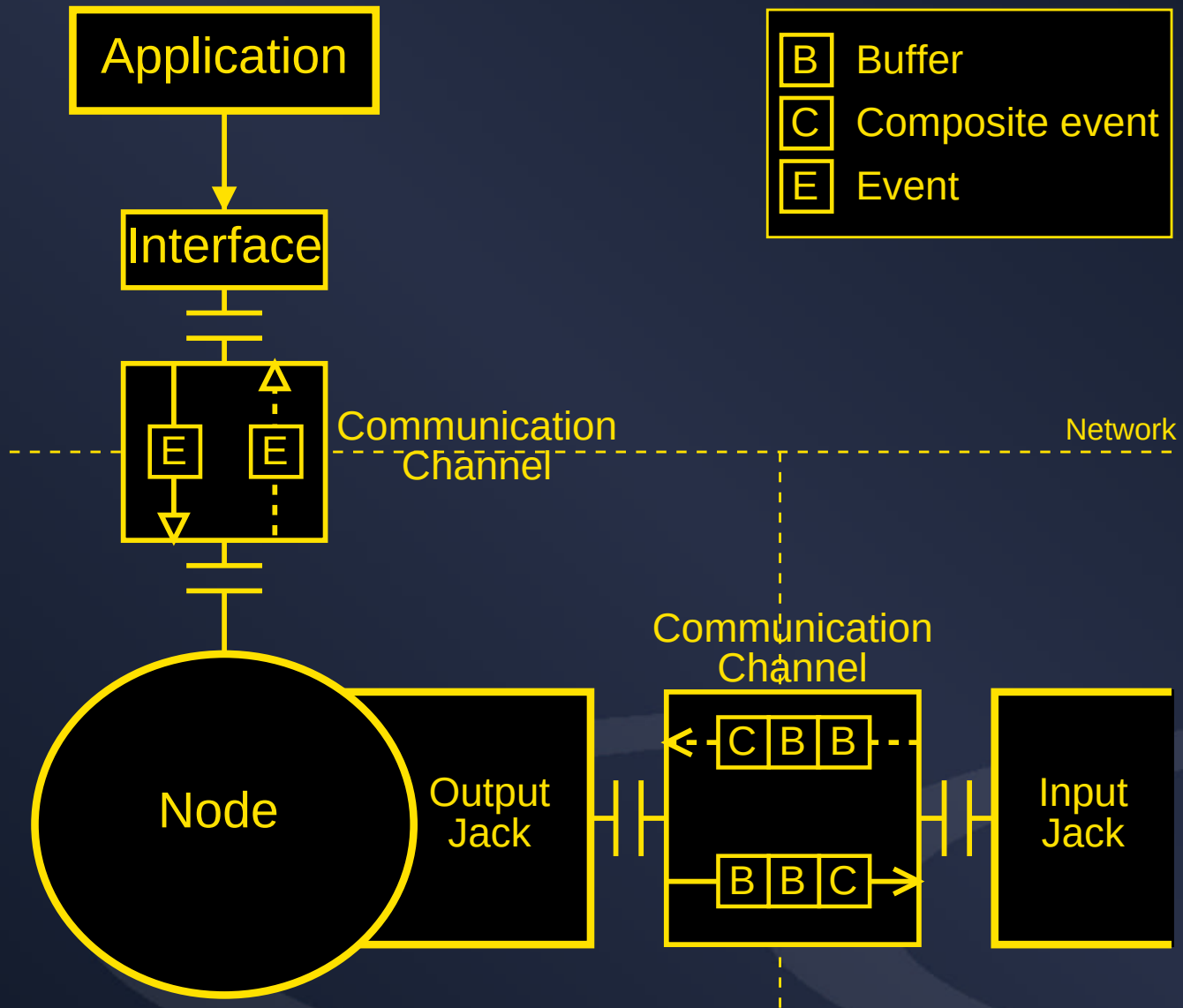
- State machine controls life-cycle



60+ Plug-ins

- Source
  - CDDA, DVD/menus, WinTV PVR, KFIR, DVB, Firewire, VISCA cameras, audio devices, WAV, AVI
- Encoder/decoder/converter/filter
  - MPEG audio, MPEG video, DivX, Ogg/Vorbis, SPU, PNG, JPEG, RTJPEG
  - Color space, video scaler, on-screen menus, deinterlacer
- Multiplexer/demultiplexer
  - AVI, MPEG, OGM
- Sink
  - Video output via X or OpenGL, audio devices, WAV, AVI

Communication Channels



Communication Channels

- Serialization and transport of objects
  - E.g. Buffers, composite events, events
- Scalable transparency
  - Automatic setup vs. manual configuration
- Serialization strategies
  - Magic number, XML, ...
- Transport strategies
  - Pointer forwarding, TCP, UDP, RTP, ...
- Local optimization
  - Pointer forwarding or elimination of communication channel

Developing Plug-ins

- Specification
  - Supported functionality? Features?
- Granularity and base classes
  - How many nodes? What kind of node?
- Implementation of (some) state transitions
  - doInit() : generally supported formats
  - doInitOutput() : currently supported formats
- Definition and implementation of interfaces
  - Out-of-band and instream interaction
- Implementation of processBuffer()
- Register node with registry service

processBuffer()

```
Message* MyConverterNode::processBuffer(Buffer *
    in_buffer )
{
  // get new buffer with defined size
  Buffer* out_buffer = getNewBuffer( out_buffer_size );
  // get data of buffer
  char* p = in_buffer->getData();
  // some code ...

  // release in_buffer since it is no longer needed
  in_buffer->release();
  return out_buffer;
}
```

processBuffer()

```
Message* MySinkNode::processBuffer(Buffer *in_buffer )
{
  // release in_buffer since it is no longer needed
   in_buffer ->release();

  // create composite event including single event
  CEvent* cevent = new CEvent(IExample::create_foo());
  // set direction to UPSTREAM
  cevent->setDirection(Message::UPSTREAM);

  return cevent;
}
```

Event Handling

- Automatic registration and dispatching due to implementation of interface
  - Out-of-band and instream interaction

```
// Implementation of IFileHandlerImpl::endTrack()
Result MySinkNode::endTrack()
{
  // handle endTrack, e.g. close file
  return SUCCESS;
}
```

Developing Plug-ins

- Modify, add, delete, replace events
- Handling multiple input and output jacks
- Handling arbitrary patterns of incoming and outgoing messages
  - Upstream and downstream traffic
  - working-flag and producing-flag
- ...

⇒ See “Developing Plug-ins for NMM”

helloworld

```
// MP3 player: the NMM application for the example
NMMApplication* app =
  ProxyApplication :: getApplication(argc, argv);

// create the node descriptions
NodeDescription  readfile ("GenericReadNode");
NodeDescription decoder("MPEGAudioDecodeNode");
NodeDescription audioplay("PlaybackNode");

// create a query for a flow graph
GraphDescription graph;
graph.addEdges(&readfile, &decoder, &audioplay);
```

helloworld

```
// request complete graph from registry
ClientRegistry & registry = app->getRegistry();
registry .requestGraph(graph);

// set the filename by requesting appropriate interface
INode* inode = graph.getINode( readfile );

IFileHandler_var filehandler (inode->getParentObject()
    ->getCheckedInterface<IFileHandler>());

filehandler ->setFilename(argv[1]);
```

helloworld

```
// realize and start graph
graph.realizeGraph();
graph.startGraph();

// wait ...

// stop complete graph
graph.stopGraph();

// release complete graph
registry.releaseGraph(graph);
```

helloNMM

```
// Distributed MP3 player:
// decoder and audio sink on remote host argv[2]
NodeDescription readfile ("GenericReadNode");
NodeDescription decoder("MPEGAudioDecodeNode");
NodeDescription audioplay("PlaybackNode");

// NEW: set location for decoder and audio sink
decoder.setLocation(argv[2]);
audioplay.setLocation(argv[2]);

GraphDescription graph;
graph.addEdges(&readfile, &decoder, &audioplay);
```

helloNMM

```
ClientRegistry & registry = app->getRegistry();

// NEW: add remote host to registry
// ( ./ serverregistry is running on remote host )
registry.addRegistry(TCPAddress(argv[2], ClientRegistry
    :: default_port ), argv[2]);

// same code as before ...
registry.requestGraph(graph);

graph.realizeGraph();
graph.startGraph();
```

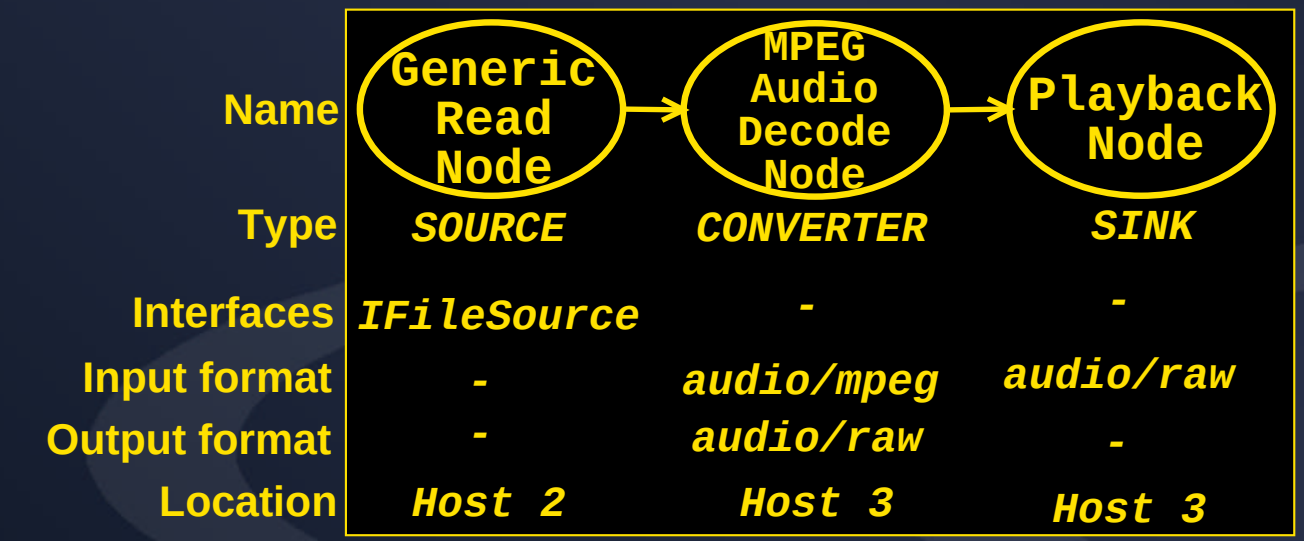
Further Options

- Node descriptions
  - Types, I/O formats, interfaces, sharing policy
- Manual creation of flow graphs
  - connect(node1, node2);
- Configuration of communication channels
  - c_connect(node1, node2);
- Listener notification
- ...

⇒ See "Hello World! Welcome to NMM Application Development :)"

Registry Service

- Administrates locally available nodes
- Queries
  - Single (subset) of a node description, or
  - Graph description
- Peer-to-peer approach for distributed flow graphs



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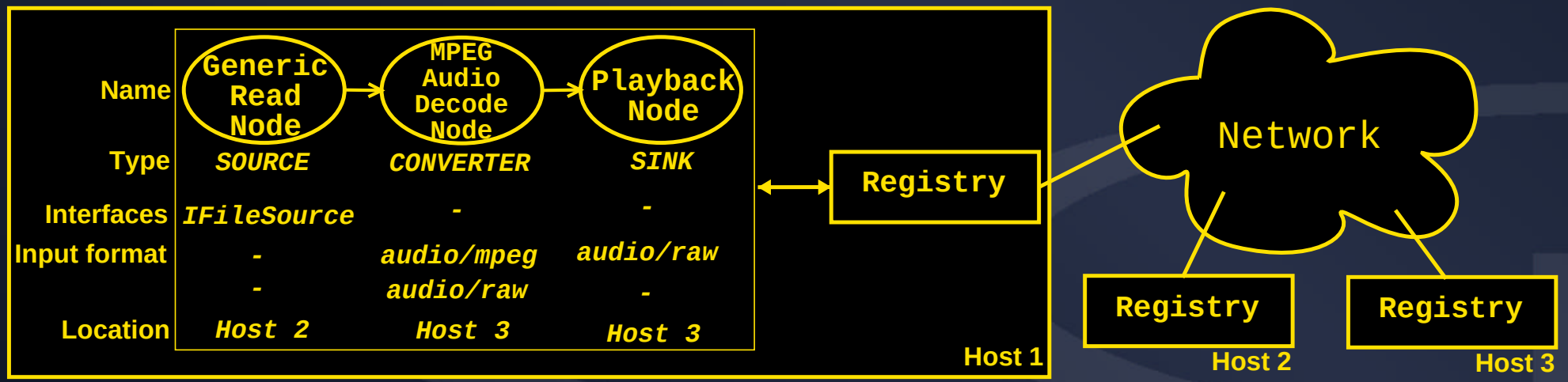


clic

- Command line interaction and configuration
- Setting up distributed flow graphs from textual descriptions
  - ./clic <.gd file> [-i <input file>] [-o <output file>]
- Examples

mp3play.gd:

GenericReadNode ! MPEGAudioDecodeNode ! PlaybackNode

./clic mp3play.gd -i /home/bob/music/song.mp3

dvbtv.gd

```
% Watch TV via DVB receiver in remote host

   DVBReadNode #Event "setChannel(1)" ACTIVATED
               #Host "host.domain.org"
! MPEGDemuxNode
{
    { ["mpeg_audio0"] ! MPEGAudioDecodeNode
                      ! PlaybackNode
    }
    { ["mpeg_video0"] ! MPEGVideoDecodeNode
                      ! XDisplayNode
    }
}
```

GraphBuilder

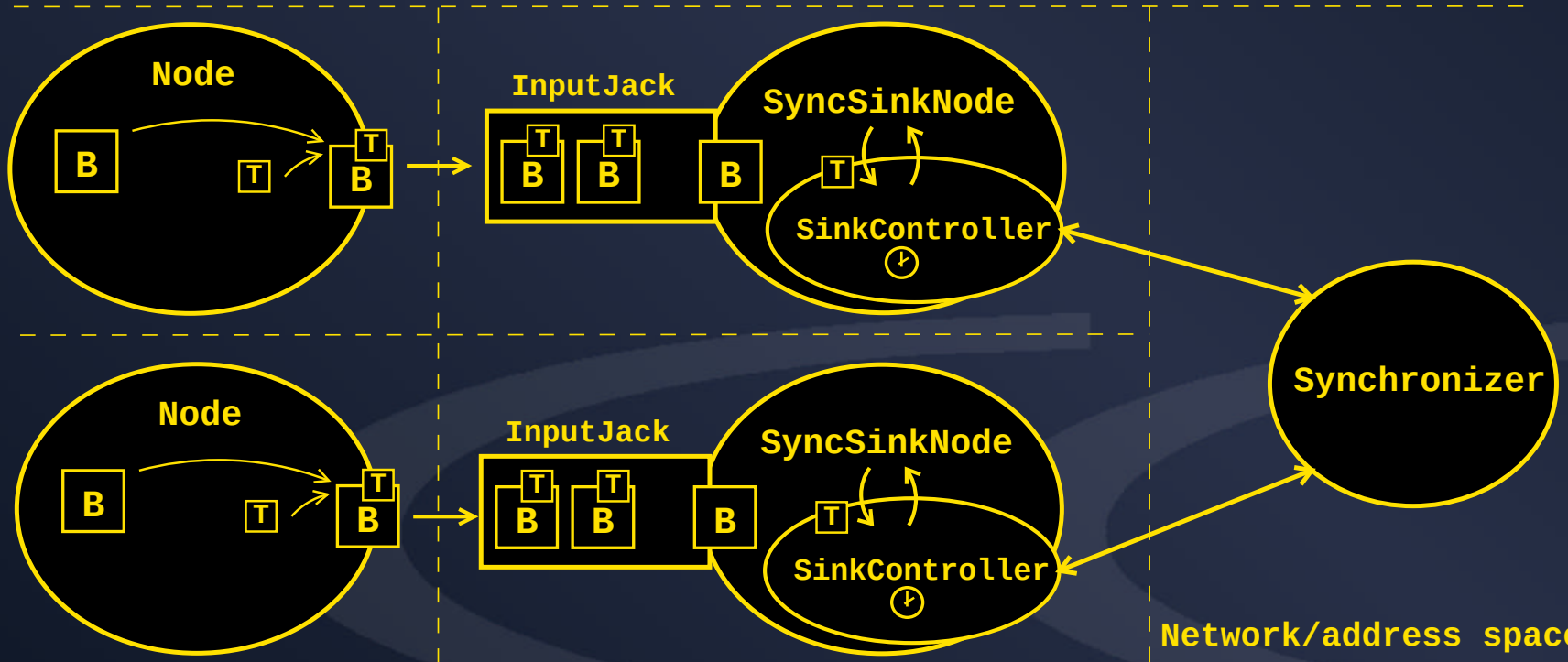
- Automatically creates distributed flow graph for media playback
  - Distributed source, audio sink, and video sink
- Supported URLs
  - file, audiocd, dvd, tv, dvbtv, ivtv, mpegtv
- Examples

```
./clic -u file:///home/bob/mp3/song.mp3
./clic -u "dvd:///dev/cdrom?title=1&chapter=4&angle=1"
./clic -u file://host1/movies/movie.mpeg -A host2 -V host3
```

⇒ Demo

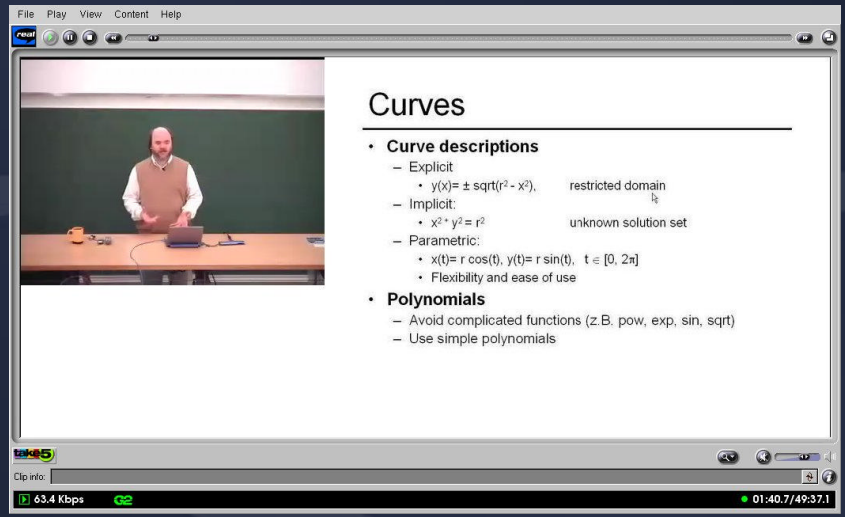
Distributed Synchronization

- Strict separation
  - Locally running controllers
  - Synchronizer globally adjusts latencies
- Global clock via NTP



Applications

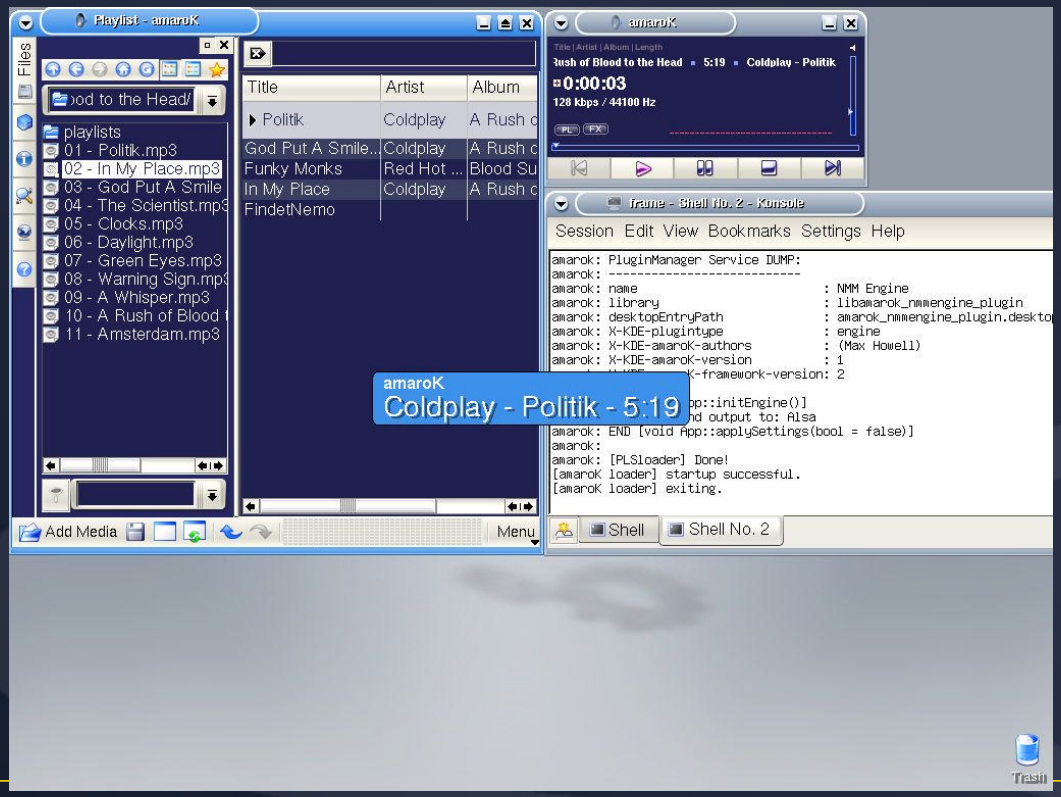
- Virtual Courseroom Environment (VCORE)
  - Record and broadcast all aspects of a talk
  - Audio and video stream of the speaker, slides, written text or annotations (SMIL)
  - Successfully used at Saarland University since winter 2002



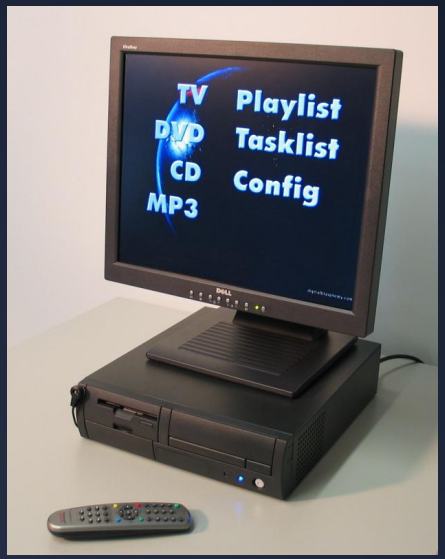
Applications

- amaroK – the audio player for KDE
  - NMM engine employs GraphBuilder (next NMM release)

⇒ Demo



Multimedia-Box



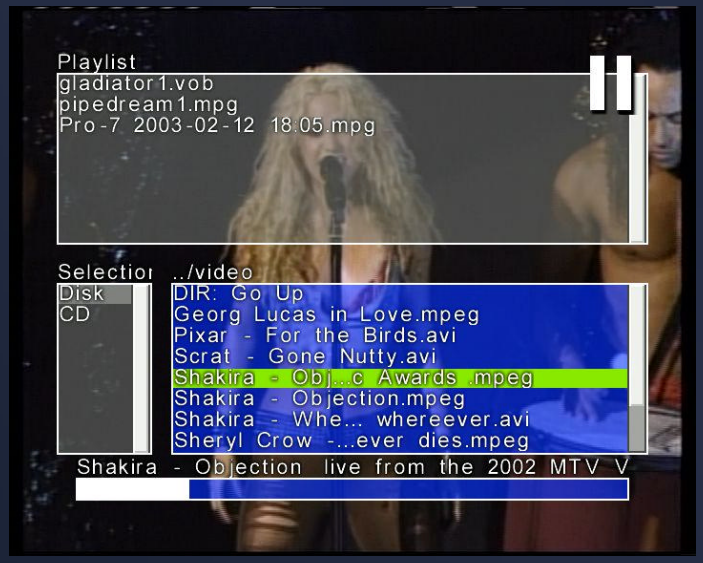
- Goal (in April 2001)
  - Networked multimedia home entertainment
- Developed completely on top of NMM
  - E.g. plug-in for on-screen display
- Seamless integration of mobile devices

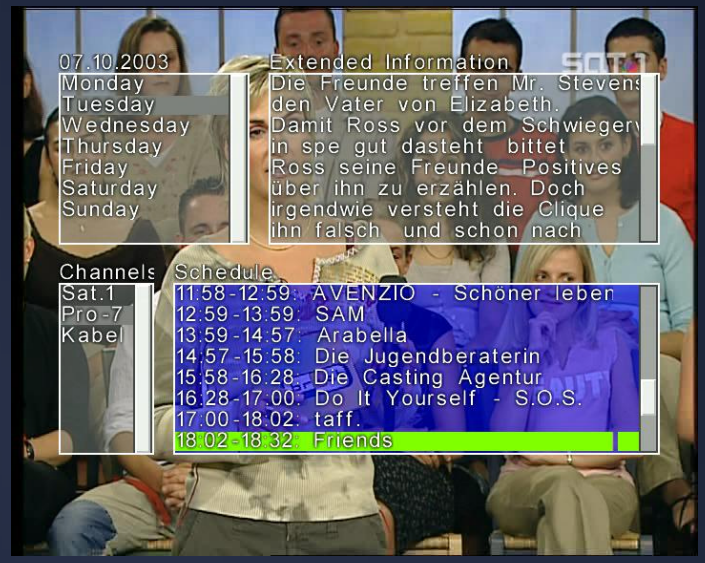
Multimedia-Box

- CD-Player with CDDB support
- CD-Grabber and transcoding to MP3/OggVorbis
- DVD-Player with support for menus
- DVD-Grabber and distributed transcoding
- TV, time-shifting, access to remote receiver
- Video recorder and Electronic Program Guide (EPG)
- Media player with playlist
- Multi-tasking: watch TV while transcoding a DVD
- Controllable with a remote-control
- Extensible and configurable application framework (XML)

Multimedia-Box

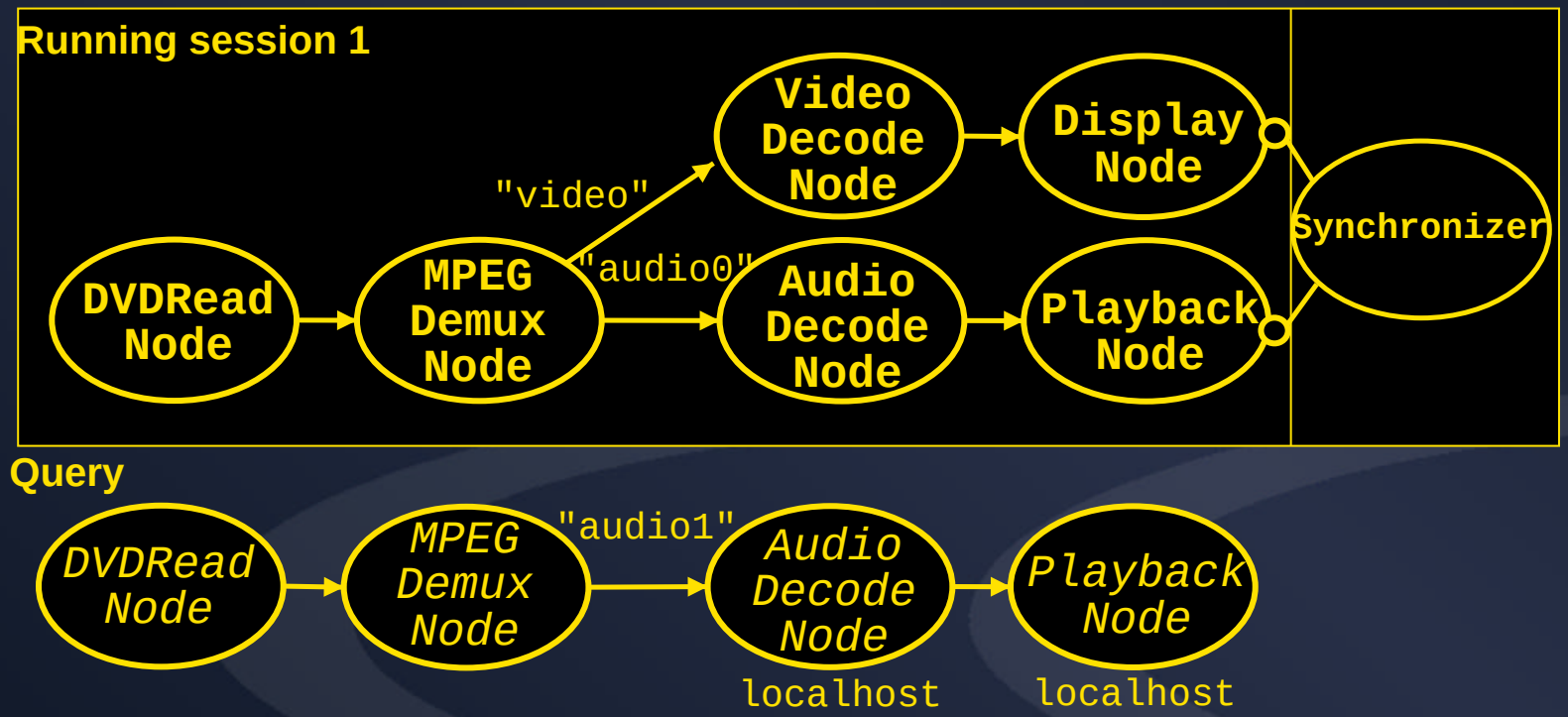
⇒ Demo





Session Sharing

- Service that allows to "overlap" running flow graph with query
  - E.g. shared access to DVD, different audio tracks for mobile devices



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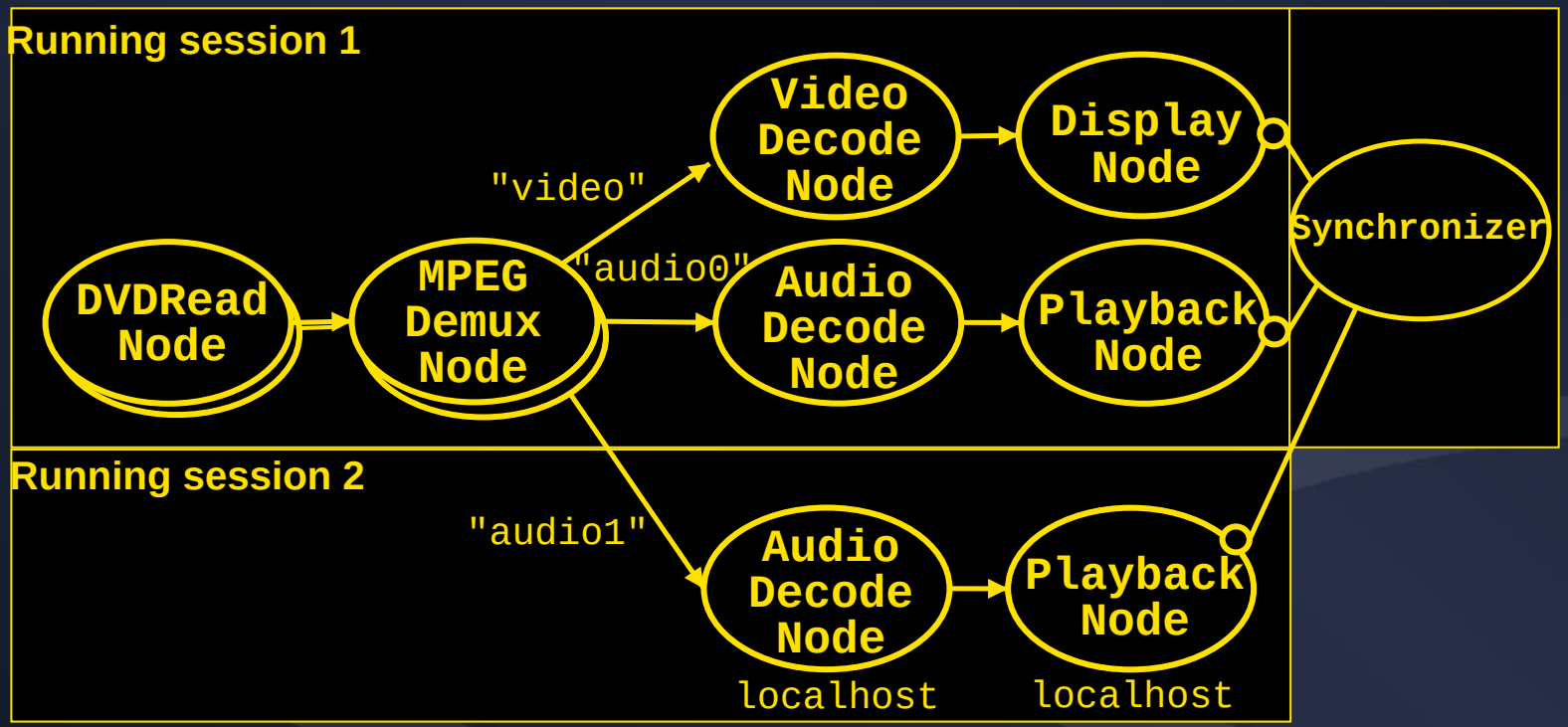
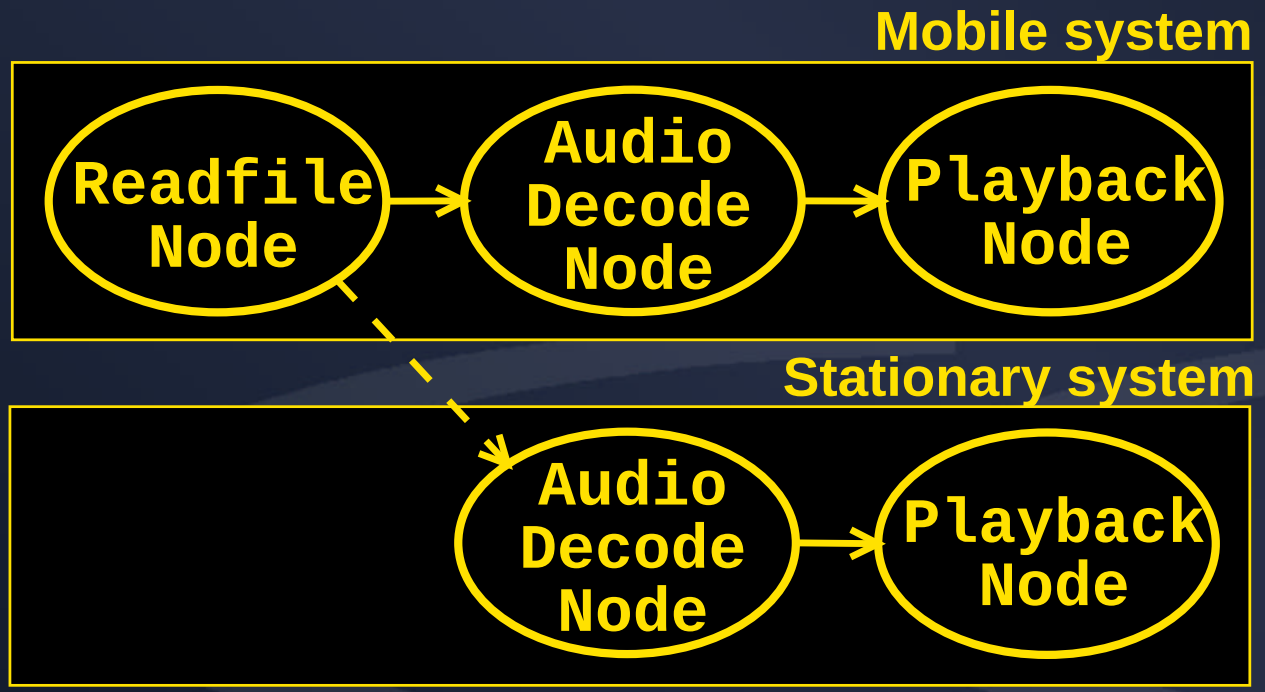


Seamless Handover

- Playback session running on mobile system
- Handed over to nearby stationary system
- Seamless and synchronized handover
  - No loss, no duplicates, no interruption



Summary

- Network-Integrated Multimedia Middleware (NMM)
  - Research project and Open Source project
- Simple, clear, and unified design
  - Nodes connected by jacks that stream messages
  - Unified out-of-band and instream interaction
- Object-oriented design
  - Inheritance for interfaces
- Integrating micro-core architecture
  - Middleware core plus plug-ins, services, transport and serialization strategies
  - No overhead for all co-located components

Summary

- Scalable transparency
  - Network as black-box vs. tuning of network parameters
- Unique features
  - Transparently distributed flow graphs
  - Distributed GraphBuilder
  - Distributed synchronization
  - Session sharing service
  - Seamless handover
- Research project with real world applications
  - Multimedia-Box, VCORE

Future Work

- Update plug-ins
- deb/rpm packages
- Optimization of current implementation
- Support for standard protocols like SIP
- Distributed streaming server with overlay network
- Intelligent distribution of workload, e.g. for transcoding
- (Help with) support for other platforms
- (Help with) integration into KDE (and other projects)

Acknowledgments

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Questions?