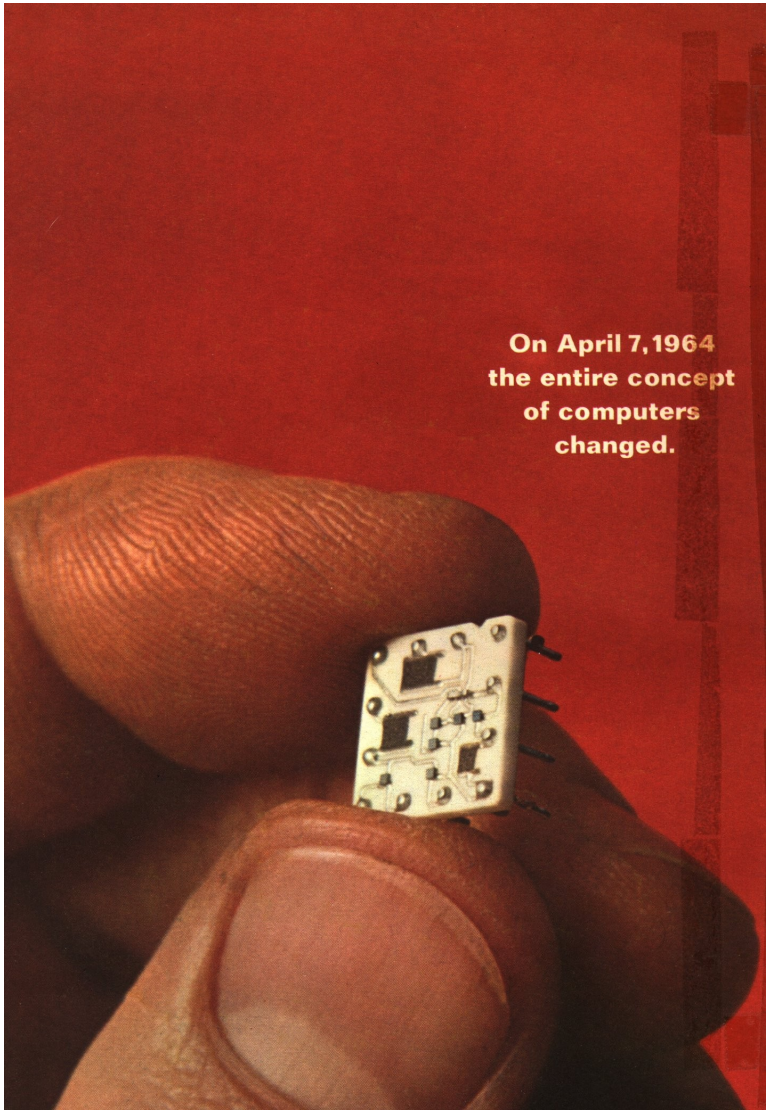
Origins of Operating Systems
OS/360

Martin Grund
HPI

Table of Contents

Welcome to Big Blue



IBM System 360

- In 1964 IBM announced the IBM-360 family for computers
  - All machines, despite their differences, had the same user instruction set
  - Different operating systems available for these machines
  - Only midrange and high-end system run OS/360
- IBM introduced the new term of hardware architecture
- In 1970 IBM announced System 370 with hardware virtual memory support

IBM System 360

- High-end machines established 32 bit as standard for computers
- Virtual Memory Support – hardware support for dynamic address translation
- Within ten years S/360 achieved standard status
- Flashback prices:
  - 1970 – $279/MB hard disk
  - 1980 - $35/MB hard disk | $50.000 /MB DRAM

IBM System 360 Specials

- Introduced 8bit entities
- Introduction of 32 or 64 bit floating point words based on a hexadecimal base
- Variable length strings using length field in the first byte
- All registers are universal registers – accumulators as well as address registers
- Registers use 32 bit, 24 bit for addressing -> 16MB

IBM S/360 - Pictures

IBM OS/360 Introduction

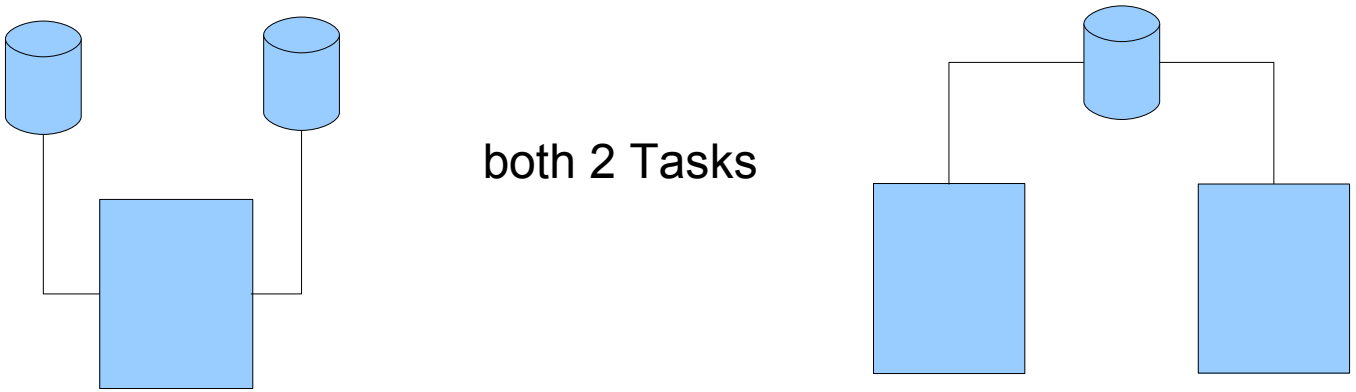
- One OS for different application areas
- Upstream compatible
- 1.000.000 program instructions, one of the most complex software ever written
- $ 50.000.000 development costs -> double the price of the Manhattan Project
- Different OS for different hardware -> small, mid-range, high-end
- MFT – small systems | MVT – high-end systems
- Introduction of JCL

OS/360 – Functional Structure

- OS/360 is one of the first “second generation” operating systems
- Primary Objective: accommodate an environment for diverse applications and operating modes
- Secondary objectives:
  - Throughput, Response Time, Productivity, Adaptability, Expandability: Support for many languages, configurations, operating modes

OS/360 – Design Concepts

- Every Program is either executed in Supervisor State or Problem State
  - S-State: for control program to call different other modules
  - P-State: all programs operate in
- Task – combination of program and data



OS/360 – Design Concepts

- Multiprogramming: for one CPU several tasks are defined
- Multiprocessing: one task utilizes several CPUs
- Multitasking allows both manners of operating
- Common System Elements:
  - Translators for programming languages
  - Linkage Editor to combine individually translated programs into one executable
  - Service Programs
  - Control Program

OS/360 – Control Program

- Main important part of the OS, contains
  - Master scheduler – control communication between operator and system
  - Job scheduler – formalizes job into task, allocation of devices, initial execution for each job step, write job output
  - Supervisor – memory management, module loading, control execution, logging, monitoring

OS/360 – System Generation

- To support as many operating modes as possible almost everything can be configured
- Each configuration leads to a new system generation
- System generation covers:
  - Support for installed libraries
  - Defining multi-task/ single-task environments
  - Defining level of concurrent jobs
- Stage I – parse generation instructions into job stream
- Stage II – load assembler, linkage editor, catalog library

Job & Task Management

- Each message arriving to the system is an independent task -> many messages can arrive at the same time
- Control program must decide which task to execute on the status of other tasks
- Basic unit of work is a JOB – can be divided into job steps -> each job step is a task
- All tasks to be executed are treated independent

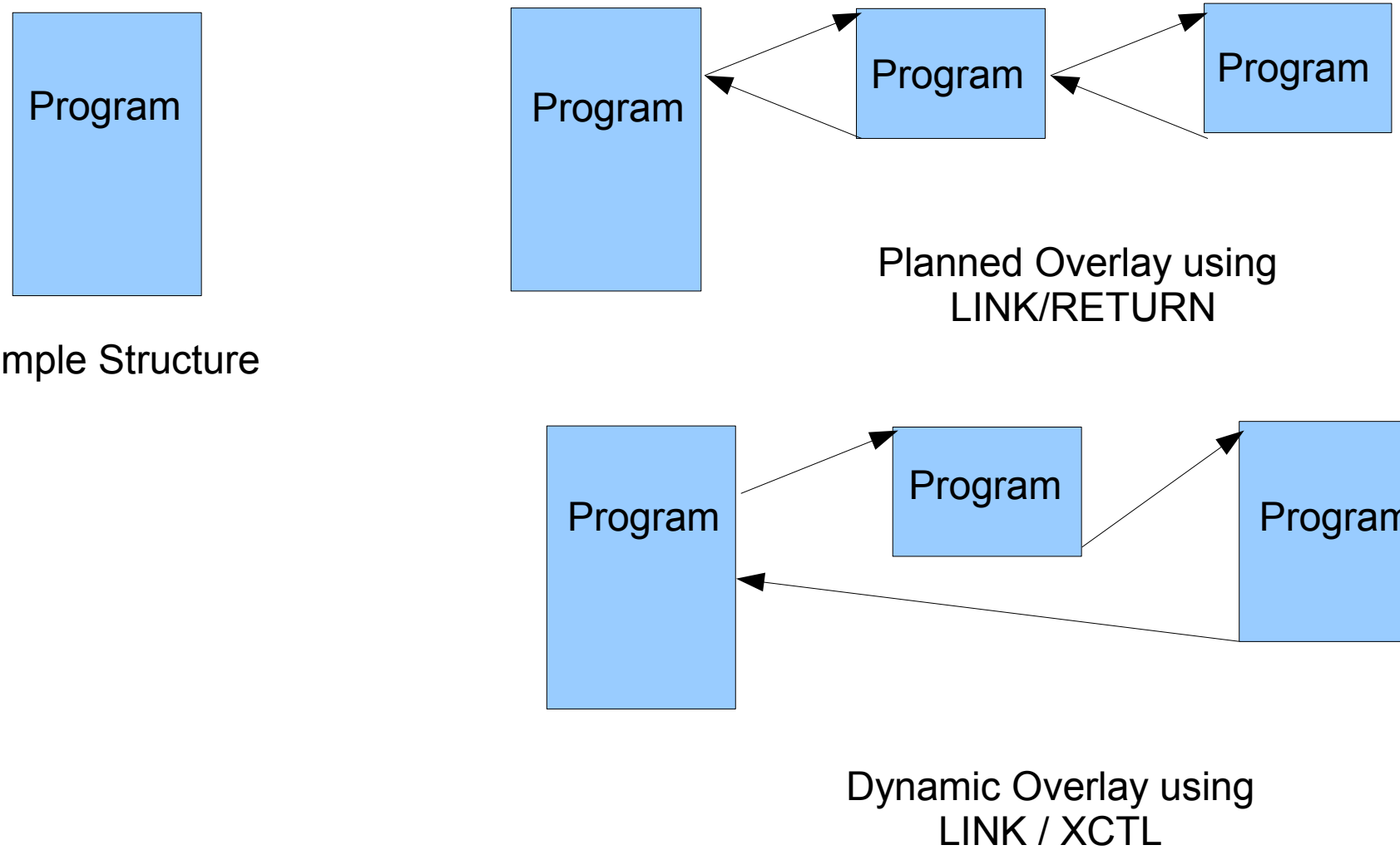
Program Structure

- All Jobs are defined using the JCL – Job Control Language
- First statement of a job is an identifier for naming, priority definition and other conditions to be matched
- Job Step Statement defines the execute part and a data definition for I/O
- Four program structures to be defined:

Program Structure

- Simple Structure
  - One load module denotes to the entire program
- Planned Overlay Structrue
  - Main Program is a single load module, but not all functionality is needed and not loaded into main storage
- Dynamic Overlay Structure
  - Load modules are called dynamically. Control is handed over using LINK, XCTRL and LOAD
- Dynamic Parallel Structure
  - Load modules are executed in parallel (modules declared as note reusable, serially reusable and reenterable)

Program Structure



Simple Structure

JCL – Job Control Language

- Scripting language to instruct the Job Entry Subsystem on how to run a batch program or start a subsystem
- JCL is defined using:
  - One or more 80-byte records
  - Must be uppercase
- It is possible to plan whole software execution steps on the forehand, independent of physical environment (using DD)
- Main instructions: JOB, EXEC, DD, PROC

JCL – Job Control Language

- //jobname JOB (accounting information),CLASS=x,MSGCLASS=x,REGION=nK,TIME=(m,s)
  - CLASS – priority definition (environmental settings)
  - MSGCLASS – how the output is printed or filed
  - REGION – size of virtual memory to use
  - TIME – total CPU usage allowed by the job, max 1439 minutes or 1440 (untimed)
- //stepname EXEC PGM=progname,PARM='parm',COND=condition,REGION=n,TIME=(m,s)
  - PGM – name of the module to be executed
  - PARM – optional parameter to the module
  - COND – defines condition when the job is NOT run
  - REGION and TIME as described above

JCL - Example

```
//PASIVP   JOB  CLASS=A,MSGLEVEL=(1,1),REGION=256K
//RUN1     EXEC PASCAL,PARM.COMPILE='COMPILATION OPTION LIST'
//COMPILE.INPUT DD *
PROGRAM Hello (Output) ;

BEGIN
  WRITELN(' Hello World!');
END.

//RUN2     EXEC PASCAL,PARM.COMPILE='COMPILATION OPTION LIST'
//COMPILE.INPUT DD *
PROGRAM fib_demo(OUTPUT) ;
TYPE pos_int = 0..30 ;
VAR  i    : pos_int ;
   time  : INTEGER ;
 FUNCTION fibonacci(j :pos_int) : INTEGER ;
 (*To evaluate fibonacci # j, for j >= 0,
                    subject to integer overflow*)
  BEGIN
```

Job Statement

Job Step Statements

OS/360 – Job Management

- Allocation of I/O devices
- Analysis of the Job Stream
- Overall Scheduler
- Direction of setup activities
- Job Management turns each task to task management – using job scheduler and master scheduler
- Scheduling done either sequential or priority based
- Either Single Job Instantiation or Multi job Instantiation

Task Management

- Single Task Management
  - Job scheduler operates as a task and executes loaded modules as subtasks (using LINK or XCTL)
  - In the end supervisor sends callback to job scheduler
- Multi Task Management
  - Main focus – resources management
  - Introduces CPU Manager – task dispatcher, task queue
  - Queue either ordered by sequence or by priority
  - All elements of the queue either in READY or WAIT state

Task Management

- WAIT – a tasks waits for a event to occur
  - Events are submitted using the POST macro
  - e.g. Read from I/O makes task wait until ready

OS/360 Resume

- Delivery too late
- Exceeded Budget
- Needed more hardware resources than planned
- Was replaced within a few years by other OS from IBM
- But:
  - Definition of new ways for Computer Science
    - Problem-State and Supervisor-State -> Kernel-Mode and User-Mode
    - LINK or XCTRL origin for todays FORK command
  - Creation of a general architecture family

OS/360 Lessons Learned

- Many concepts for todays operating systems were introduced in OS/360
- Complexity of Installing/ Running an OS were reduced heavily
- Today OS/360 can be run on almost any machine using the Hercules emulator and is freely available as public domain software

Virtual Machine Time Sharing

- Approach to maximize the utilization of a single system
- Simulate the whole underlaying system
  - In the beginning: S/360 40 with new modification for memory address translation mechanisms (later S/360 67)
- Combination of VMCP/CMS on S/360 40 was developed on the MIT
- Virtual Machine Control Program – provide functionality for time-sharing, resource allocation, system handling
- CMS – Simple single user Monitoring System for S/360

VM Environment

- VM simulates the whole system
- Support for many OS like OS/360, DOS/360, RAX...
- 24bit addressing region used to assign virtual memory to each guest system
- I/O partitioning – VM devices are mapped onto real devices
- Requirements: not real-time dependent, almost same machine instruction set used by OS, guest OS must support privileged and unprivileged mode
- VM must be isolated and CP must be protected

VM – Paging Explained

- Since cumulated size of main storage for all VMs exceeds main storage of the host, virtual addressing is needed
- Virtual main storage is divided into 4096 byte blocks (pages) -> all active pages are kept in main memory, other pages are swapped to secondary memory
- Dynamic address translation translates address into the current real memory
- Each VM has its own main memory

Demo

- Start OS/360 – execute simple Job from the main terminal to compile and run a Pascal program
- Show S/360 with TSO to show VM mechanisms

Q & A

Any Questions?

Literature

[1] http://en.wikipedia.org/wiki/OS/360

[2] Download of OS/360 - http://www.ibiblio.org/jmaynard/

[3] OS/360 Distribution - http://open360.copyleft.de/OS360/Download.html

[4] System/360 Announcement - http://www-03.ibm.com/ibm/history/exhibits/mainframe/mainframe_PR360.html

[5] Computer History IBM 360/370/390 - http://www.beagle-ears.com/lars/engineer/comphist/ibm360.htm

[6] The IBM 360/67 CP and CMS - http://www.multicians.org/thvv/360-67.html

[7] The iron penguin - http://www.itworld.com/Comp/1369/LWD000606S390/

[8] History of Computes – OS/360 - http://www.imn.htwk-leipzig.de/~yal-bil/

[9] Job Control Language - http://en.wikipedia.org/wiki/JCL

[10] IBM Systems Journal – A virtual machine time sharing System

[11] IBM Systems Journal – The functional structure of OS/360

[12] Amdahl et al, Architecture of the IBM System/360

[13] MVS Tur(n)key System - http://www.bsp-gmbh.com/turnkey/