4. Families of Systems
Overview of SCS4, Again

1. *rigorous description* of requirements
2. *what information* should be provided in computer system documentation?
3. *decomposition* into modules
4. *families* of systems
Overview of Chapter 4: Families of Systems

4.1 motivation:
  maintenance problems in telephone switching

4.2 families of programs

4.3 families of requirements
4.1 Motivation: Maintenance Problems in Telephone Switching
Overview of Chapter 4.1

• background on telephone switching

• feature interaction problems in telephone switching
# History of Telephone Switching Systems

<table>
<thead>
<tr>
<th>Decade</th>
<th>System Description</th>
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</thead>
<tbody>
<tr>
<td>1950s</td>
<td>direct distance dialling (DDD)</td>
</tr>
<tr>
<td></td>
<td>No. 5 Crossbar</td>
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<tr>
<td>early 1960s</td>
<td>stored program control switches</td>
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<tr>
<td>1976</td>
<td>Signalling System No. 6</td>
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<tr>
<td>1980</td>
<td><em>Signalling System No. 7</em></td>
</tr>
<tr>
<td>1984</td>
<td><em>ISDN</em></td>
</tr>
<tr>
<td>currently</td>
<td>IP telephony</td>
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Signalling System No. 7

OSI model
- application layer
- presentation layer
- session layer
- transport layer
- network layer
- data link layer
- physical layer

SS7 architecture
- OMAP
- ASEs
- TC
- ISUP
- TUP
- SCCP
- MTP Level 3
- MTP Level 2
- MTP Level 1

OMAP: Operations, Maintenance and Administration Part
ASE: Application Service Element
TC: Transactions Capabilities
ISUP: ISDN User Part
SCCP: Signalling Connection Control Part
MTP: Message Transfer Part
TUP: Telephone User Part
ISDN/DSS1

- Integrated Services Digital Network

- basic service:
  - two B-channels (64 kbit/s, transparent)
  - one D-channel (16 kbit/s, for signalling, e.g., call setup)

  ▶ protocol: Digital Subscriber Signalling 1 (DSS1)

- supplementary services:
  - Calling Line Identification Presentation
  - Call Forwarding
  - Closed User Group
  - User-to-User Signalling
  - . . .
• fixed set of supplementary services
Intelligent Network (IN)

- extension of telephone switching systems
- general goals:
  - rapid introduction of new services
  - broaden range of services
  - multi-vendor environment
  - evolve from (all) existing networks
- standardized by ITU-T
- approach: base service & additional services/features
- new services step by step:
Intelligent Network Conceptual Model (INCM)

- four “levels”:
  - service plane
  - global functional plane
  - distributed functional plane
  - physical plane
Global Functional Plane

- service independent building blocks (SIBs)
- service logic ("glue" for SIBs)
- basic call process
  - is special SIB
  - POI: point of initiation (of service)
  - POR: point of return
Services in IN CS-1

- Abbreviated dialling
- Account card calling
- Automatic alternative billing
- Call distribution
- Call forwarding
- Call rerouting distribution
- Completion of call to busy subscriber
- Conference calling
- Credit card calling
- Destination call routing
- Follow-me diversion
- Freephone
- Malicious call identification
- Mass calling
- Originating call screening
- Premium rate
- Security screening
- Selective call forward on busy / don’t answer
- Split charging
- Televoting
- Terminating call screening
- Universal access number
- Universal personal telecommunications
- User-defined routing
- Virtual private network
• 25 services

• kind of services limited:
  ○ mainly for call setup and call tear down
  ○ 1 customer and 1 call leg only, mostly

• set is “political”:
  ○ some services very similar
    ▶ taken from different sources, without proper merge
    ▶ example: Televoting / Mass Calling
Features in IN CS-1

- Abbreviated dialling
- Attendant
- Authentication
- Authorization code
- Automatic call back
- Call distribution
- Call forwarding
- Call forwarding on BY/DA
- Call gapping
- Call hold with announcement
- Call limiter
- Call logging
- Call queueing
- Call transfer
- Call waiting
- Closed user group
- Consulation calling
- Customer profile management
- Customized recorded announcement
- Customized ringing
- Destinating user prompter
- Follow-me diversion
- Mass calling
- Meet-me conference
- Multi-way calling
- Off net access
- Off net calling
- One number
• Origin dependent routing
• Originating call screening
• Originating user prompter
• Personal numbering
• Premium charging
• Private numbering plan
• Reverse charging
• Split charging
• Terminating call screening
• Time dependent routing

• 38 features
Architecture of Distributed Functional Plane

- - - - - voice
- - - - - signalling
- - - - - control
- - - - - management

service management

service control

call control

Basic Call State Model

- originating BCSM
- terminating BCSM
Feature Interaction Problems in Telephone Switching

• features work separately, but not together
  ○ hundreds of (proprietary) features
  ○ combinations cannot be checked anymore

• telephone switching
  ○ users’ expectation high

• feature
  ○ about any increment of functionality
Calling Card & Voice Mail

• #-button
  ○ (Bell) calling card:
    start new call without re-authorization
  ○ (Meridian) voice mail:
    end of mailbox number, end of password, . . .

• call voice mailbox using calling card??
  ○ either early disconnect, or
  ○ calling card feature crippled

• resolution by Bell
  ○ introduce new signal:
    “#-button pressed at least 2 sec.”
Call Waiting & Call Forward on Busy

- both activated simultaneously
  - in busy state
  - when another call arrives
- only one can get control
  - no resolution, except restrictions on features
Originating Call Screening & Area Number Calling

- **OCS**
  - aborts calls to numbers in list
  - query Service Data Point (SDP) for list

- **ANC**
  - dialled number + area(calling number) → called number
  - example: Domino’s Pizza
  - query SDP for called number
• switch may restrict no. of queries
  ○ protection against infinite loops
  ○ e.g., one query per call
  ○ → OCS subscription prevents orders for pizza

• solution: one more query??
Calling Number Delivery & Unlisted Number

• conflict of goals
  ○ CND reveals caller
  ○ UN prevents revealing caller

• resolution
  ○ weaken one feature
  ○ e.g.: CND delivers only 1-111-1111-1111
    for unlisted number
Call Forwarding & Terminating Call Screening

- **CF**
  - B forwards all calls to C

- **TCS**
  - when A is caller, C blocks him

- A calls B: can/should A reach C?

- notion of “caller” is crucial
Informal Feature Interaction Definition in Literature

- **Fi:**
  
  *the behaviour of a feature is changed by another feature*

- not precisely clear what a feature actually is

- not all interactions are undesired
Categorization of Causes

according to [Cameron et. al.]:

• violation of feature assumptions
  ○ naming
  ○ data availability
  ○ administrative domain
  ○ call control
  ○ signalling protocol

• limitations on network support
  ○ limited CPE signalling capabilities
  ○ limited functionalities for communications among network components
• intrinsic problems in distributed systems
  ○ resource contention
  ○ personalized instantiation
  ○ timing and race conditions
  ○ distributed support of features
  ○ non-atomic operations
Approaches for Tackling FI

• ignore
• informal
  ◦ filtering
  ◦ heuristics
  ◦ . . .
• formal methods
  ◦ validation of:
    ▶ specified properties of the features
    ▶ general properties of the system
      (free of non-determinism, . . . )
• new architectures
  o IN
  o Tina, Race, Acts
  o DFC, agents

• better software engineering processes

• in practice: ignore / informal / processes / (architectures)

• formal analysis?
  yes, but. . .
  o formalization is huge task
  o complexity not amenable to tools
    ▶ “spaghetti code” dependences
Feature Interactions in the Requirements

- if requirements complete, all FI are (inherently) present in the requirements
Requirements Structuring Problems

- monolithic requirements or single layer of extension
  - ISDN: monolithic
  - IN: no features on top of features
  - CF & TCS: resolution needs extended, common notion of caller
  - CF & OCS: resolution needs extended, common notion of called user
new services depend implicitly on new concepts

- some new concepts:
  - conditional call setup blocking
  - dialled number translation
  - multi-party call/session
    - required for CF & TCS and for CF & OCS
  - service session without communication session
  - distinction user – terminal device
  - distinction user – subscriber
  - mobility of users and of terminals
    - difficult to specify with network of distributed switches
  - multiple service providers, billing separately
• concerns of the users’ interface are spread out
  ○ several features assume exclusive access to the user’s terminal device (12 buttons + hook)
  ○ example: calling card & voice mail
Needed: a More Modular Requirements Structure

- centralize responsibility for the users’ interface
- a layered architecture
  - like in computer communication systems
New Architectures

- **current**: IN
  - currently largest impact on implementations
    ▶ see above
  - Jain
    ▶ enhanced IN-like architecture
    ▶ developed currently
    ▶ in Java
    ▶ allows multi-party, multi-media calls
    ▶ Java Call Control (JCC):
      call state machine similar to that of the IN
    ▶ JCC does not handle feature interactions
future: Tina, Race, and Acts

Tina
- radical approach: entirely new architecture
- strongly based on Open Distributed Processing (ODP) and Corba
- migration difficult

Race project
- Cassiopeia
  - developed open services architectural framework (Osa)
  - many commonalities with Tina
  - focuses on requirements engineering of services
  - tries to take legacy services into account

Score
- concerned with the methodological aspects of service creation
- detection of undesired service interactions:
  - formal methods, exhaustive simulation
  - applied to small example
○ Acts project
  ▶ followed Race project
  ▶ application and on evaluation of service architectures
  ▶ result: a modified architecture
• **research: the DFC and the agent architecture**
  ○ **Distributed Feature Composition (DFC)**
    ▶ compose features in a pipe-and-filter network
    ▶ designed to be implementable on a conventional switch
    ▶ some new concepts supported, others not
    ▶ no layered architecture
    ▶ implemented in AT&T’s Eclipse project, which additionally incorporates Voice Over IP
  ○ **Zibman et. al.’s agent architecture**
    ▶ separates several concerns explicitly
    ▶ restricts itself to narrow-band telephony over a fixed network
    ▶ Plain Old Telephone Service is represented by a single service agent
Discussion of New Architectures

• IN important step, but not sufficient
• Tina, Race, Acts have most of the interesting concepts, but transition is very expensive
• feature interaction detection is still research
• some undesired service interactions still possible in new architectures
  ○ a paper checked the FI benchmark for Tina
  ○ still possible:
    ▶ forwarding loop
    ▶ automatic callback & automatic re-call
    ▶ calling number delivery & calling number delivery blocking
    ▶ billing problems for video conference
    ▶ . . .
  ○ causes: violated assumptions or conflicting goals
• how to prepare for unanticipated changes??
  ○ at least encapsulate as much as possible