

# **Adaptation in Software Radio using a Complex Organic Distributed Architecture (CODA)**

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This document is based on work carried out in the EU  
sponsored collaborative research project CAST  
Nonetheless only the authors are responsible for the views  
expressed here

# What we will cover:

Aims of the CAST project

CODA in the CAST project

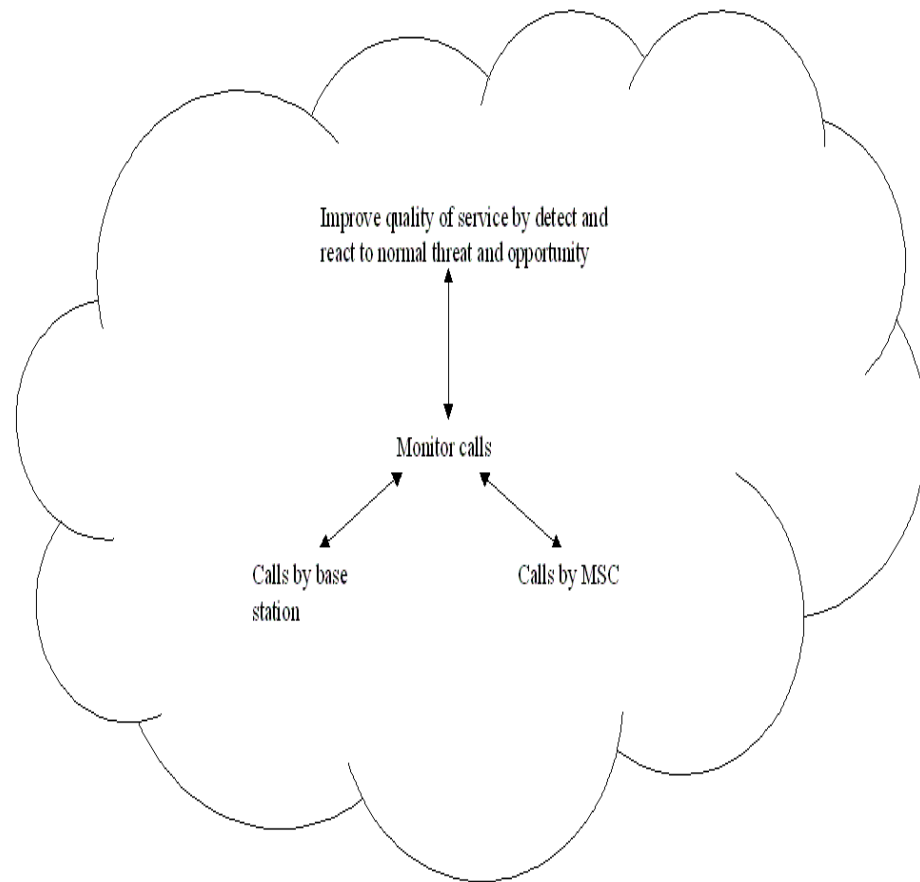
An overview of CODA Intelligence

The CODA Sub-system

The Application Programs

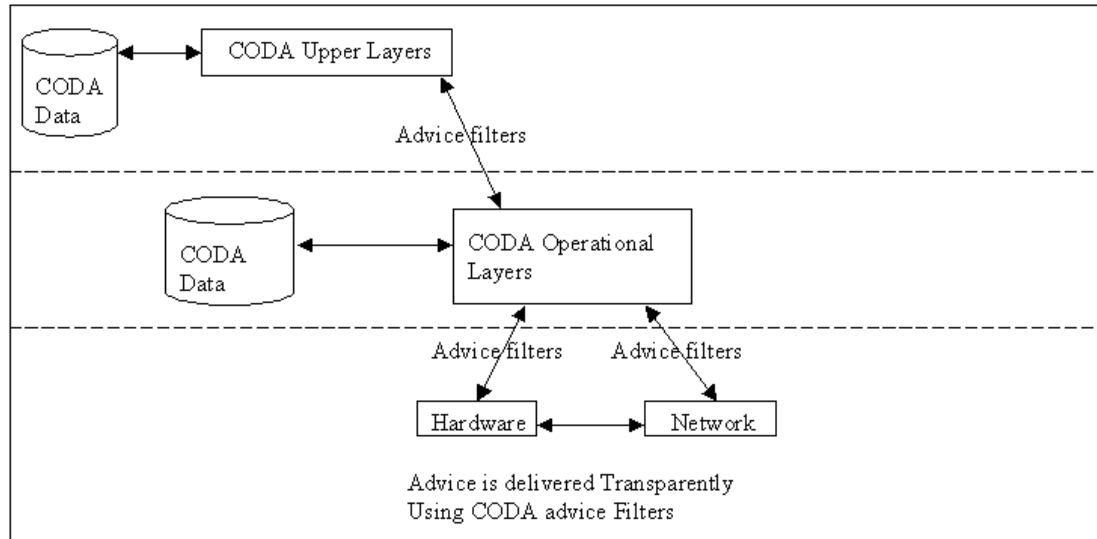
## Mobile phone Subsystem

Environmental variables



# Aims of the CAST Project

CODA is a complex organic distributed architecture which was used to deliver intelligent to reconfigure the hardware components of a mobile network transparently.



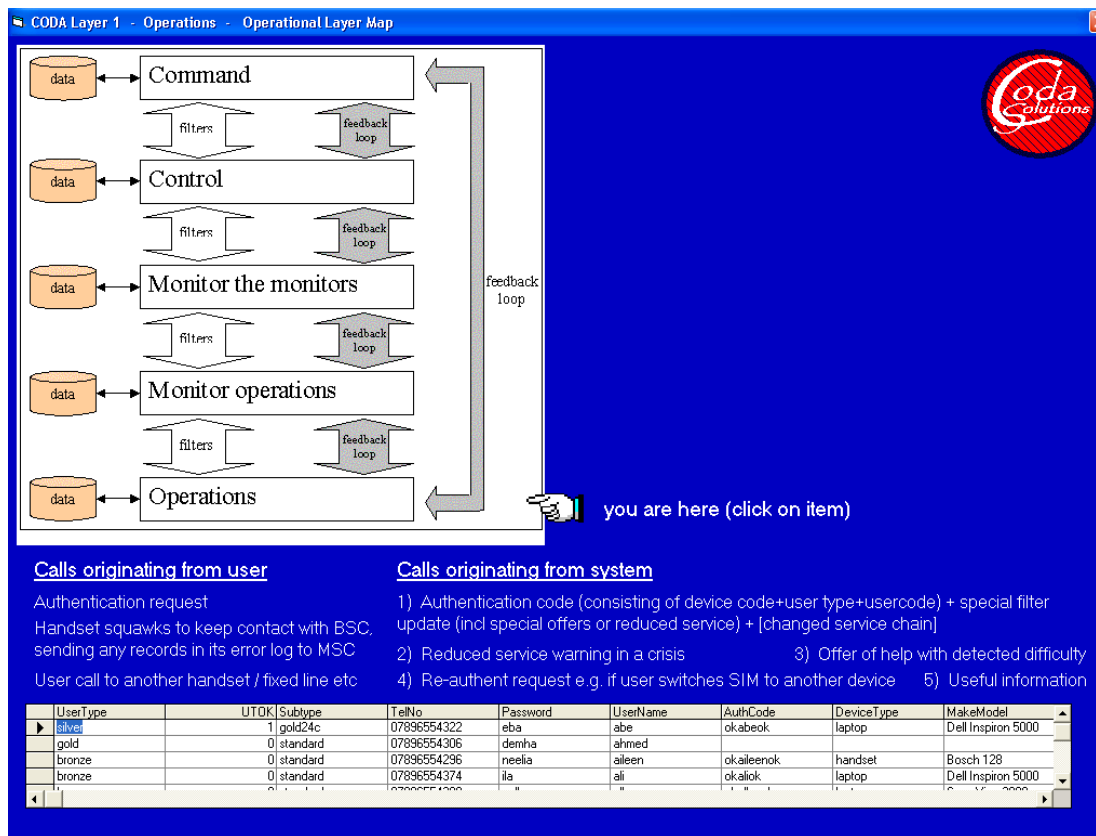
The aim of the intelligence system was to deliver the best quality of service under a variety of environmental conditions.

# CODA in the CAST Project

CODA is made up from five interacting layers

Each layer contains roles tasks and data stores

The model is drawn from cybernetic, cognitive research and knowledge discovery systems.



The CAST project sub-system is made up from three layers of CODA.

In a full CODA implementation this sub-system would interact transparently with every other part of the network to ensure a cohesive and seamless response to the environment

Quality of service involves identifying user trend behaviour over time as well as immediate response to various environmental conditions

## **An overview of CODA Intelligence**

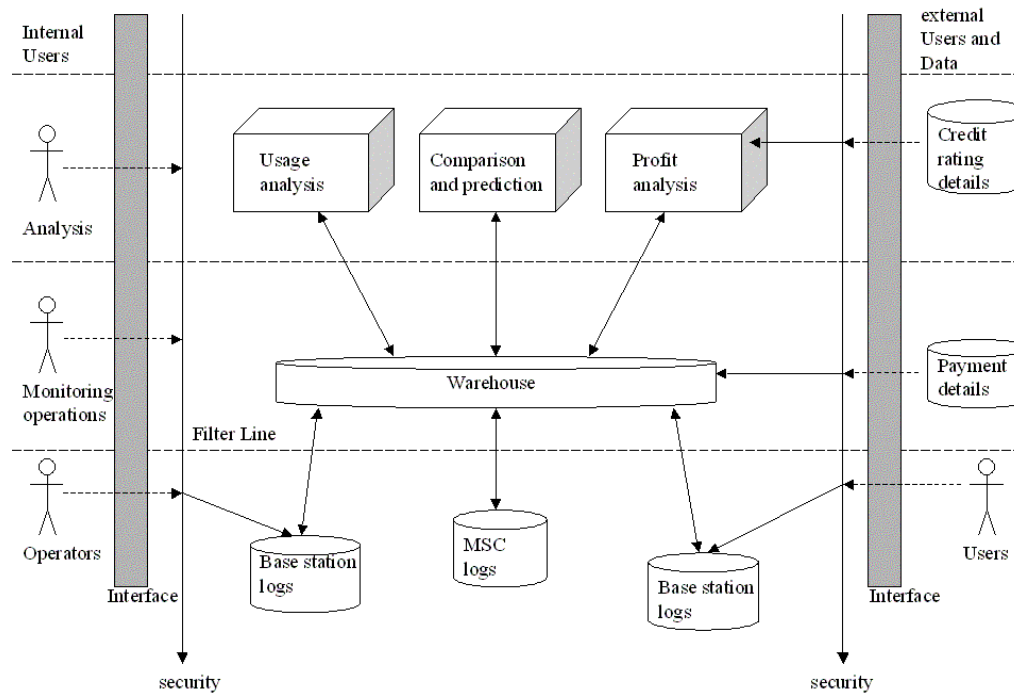
CODA is a five layered architecture.

Each layer contains roles, cells, and memory.

Interaction between all components is managed by filters. The feedback loop ensures that the system is able to adapt to the environment intelligently

# An overview of CODA Intelligence

This overview shows the sub-system constructed for the CAST project

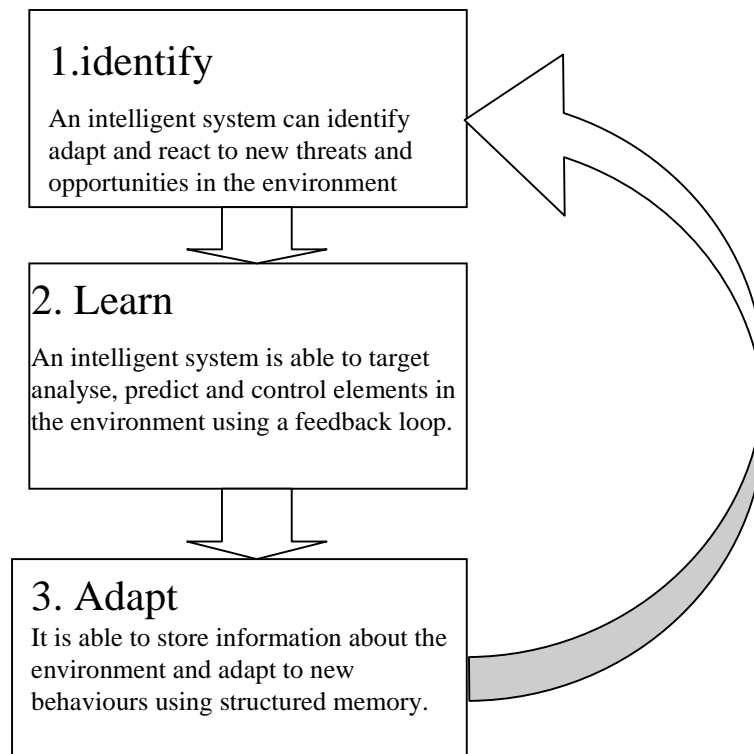


Component cells in the sub-system co-operate to meet an objective

# A CODA Sub-system

## The Intelligence Cycle

Intelligence in CODA components depends on the use of memory to adapt



# The Demonstration Scenario

## The Test Process

Complexity Type	CODA Solution
Complex Data	Tasks are organised by cells initiated by roles and measured by CSFs
Complex Data	Data is Restructured using CODA warehouses according to viewpoint and layer
Complex Interactions	Objectives are undertaken by subsystems and managed via the feedback loop
Overall test	Performance Improved



## Producing Test Data

A 'real' environment requires the expression of time, group and location variables as a minimum.

Environmental conditions can be normal, threat or opportunity.

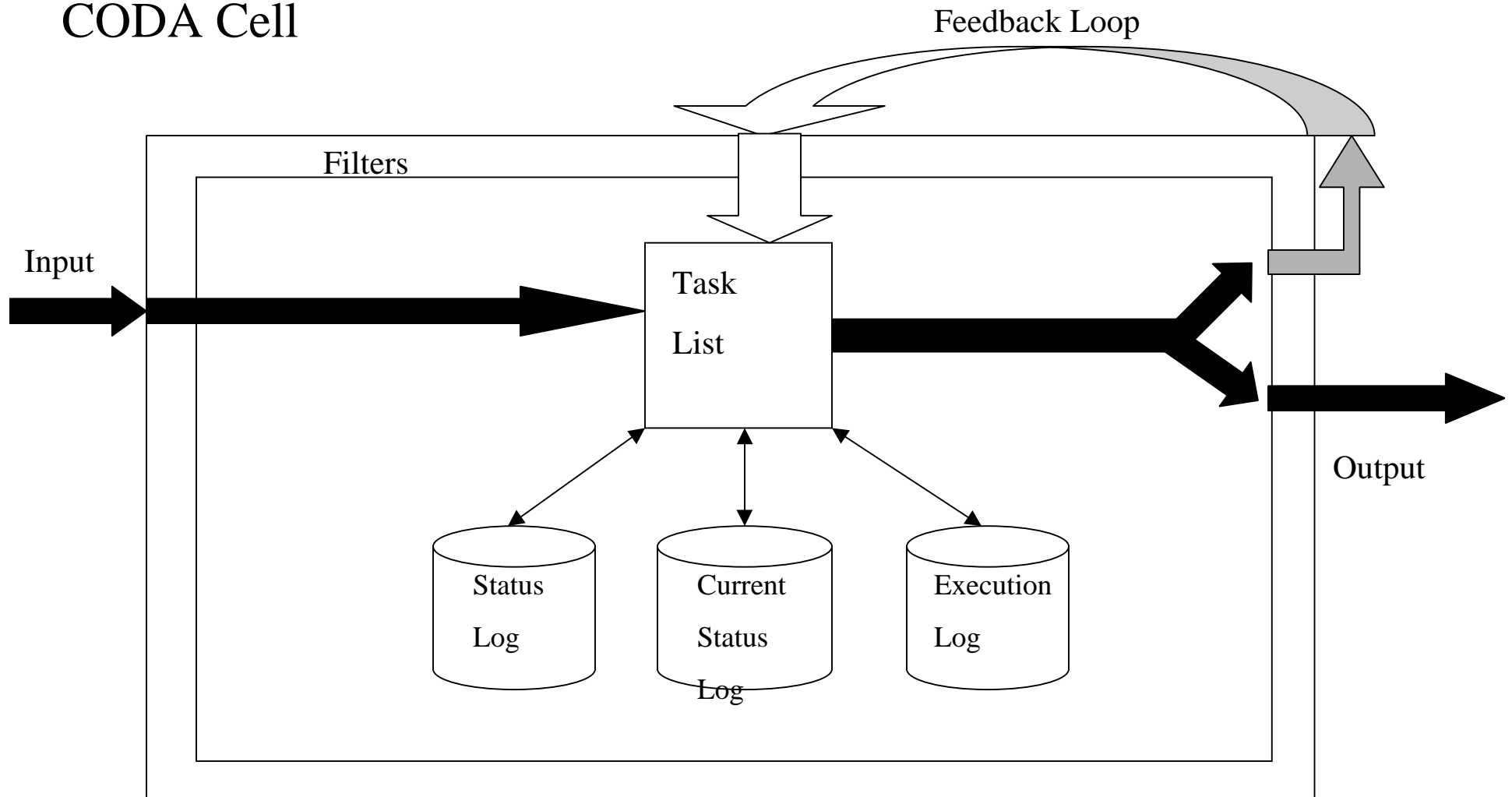
Within this environment, variety in the group dimension, expressed as objects of interest, occurs in the users and calls.

Scenario for 30/01/2003

Count of event	servicetype ▼									
event ▼	fax	jpeg	mp3	sms	video	voice	wap	www	Grand Total	
start		798	805	600	5078	603	5399	659	801	14743
Grand Total		798	805	600	5078	603	5399	659	801	14743

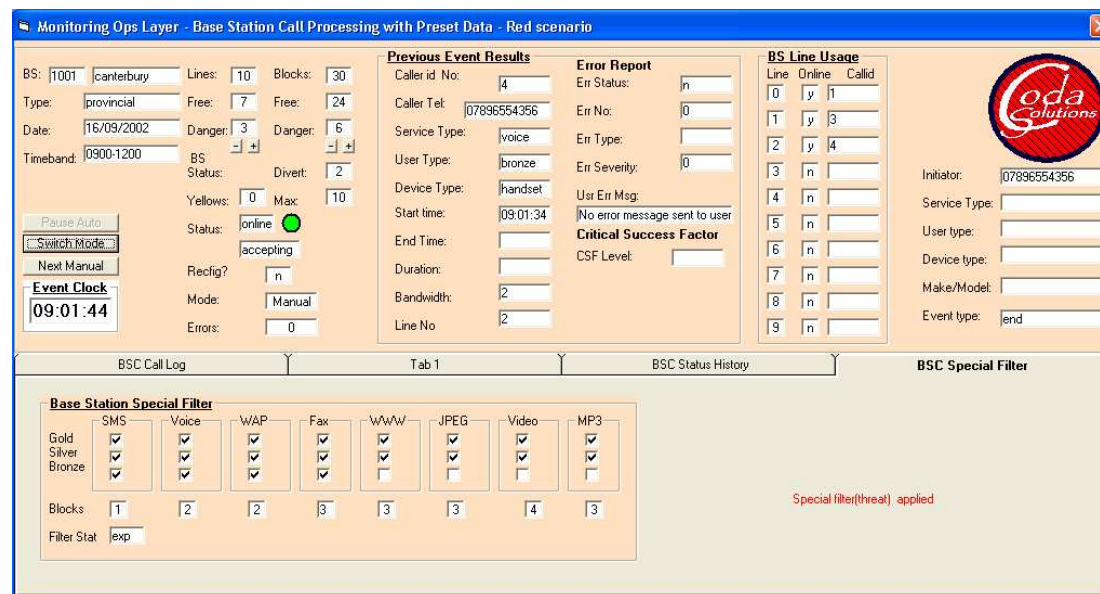
Calls originate from various users with different types of mobile devices, contracts and service requests. Users are at 10 possible BSC locations. Calls occur over a timeband on a day-type, (the test environment only considers one non-holiday weekday).

# CODA Cell



CODA Cells are based on organic systems. They are pre-set with operational parameters known as critical success factors and operate semi-autonomously unless they cannot meet operating tolerances.

This is an implementation of a CODA Cell in the CAST scenario



The BSC cell filters and critical success factors can be viewed and adjusted by an operator as the system manages calls. Otherwise adjustment is fully automated

## Failure CODES

The special filter settings are Adjusted by the CODA intelligence cells

Depending on the types of failures cells are reporting.

An example of the call failure types is shown here

The failure details are stored in the operating log of the cell which failed and sent to the intelligence layers

Failure type	
code	Code description
0	Call ok
1	1 divert used
2	2 divers used
3	Receiver busy
4	Receiver cannot take
5	Mobile device failure (caller)
6	Mobile device failure (receiver)
7	Receiver BSC rejects non-contract call (BSC yellow/red)
8	Start BSC rejects non contract call (BSC yellow/red)
9	Start BSC filters out a non contract call
10	MSC filters out non contract call (not in demonstrator)
11	Receiver BSC fails to divert contract call
12	Caller BSC can't divert a contract call
13	Caller BSC filters out a contract call

service request	User cell details		
		user online	
service type	user filters	status logs	user logs
	ok	ok	yes
	ok	ok	yes
	ok	ok	yes
	ok	busy/offline	yes
	receiver filter	0	yes
	ok	ok	yes
	ok	ok	yes
	ok	ok	yes
	ok	ok	yes
	ok	ok	yes
	ok	ok	yes

BSC cell details		
	BSC status {Red Green Yellow}	
BSC filters		BSC logs
ok	G	yes
ok	R/Y	yes
ok	R/Y	yes
ok	0	0
ok	G	yes
ok	Y/R	yes
ok	Y/R	yes
ok	any	yes
not	Y/R	yes
not	Y/R	yes
ok	Y/R	yes

Calls may fail in any one of the three interacting operational cells: MS,BSC,MSC

MSC cell details			Cell failure code
	MSC status {Red Green Yellow}		
MSC filters		MSC logs	Failure codes
ok	G	yes	0
ok	G	yes	1
ok	G	yes	2
ok	0	yes	3
ok	G	yes	4
ok	G	yes	7
ok	G	yes	8
0	0	yes	9
ok	G	yes	11
ok	G	yes	12
0	G	yes	13

# Testing a Complex System

## Proof of Intelligence

The sub-system adapts to the variety in this environment. As calls are executed, the sub-system attempts to adapt to and modify the environment by either restricting or encouraging usage to make effective use of the lines and bandwidth available by means of special filters.

city	downtown	crisis	weekday	30/01/2003	1500-1800	6	yyy	yyn	nnn	nnn	nnn	nnn	nnn	nnn
westend	downtown	crisis	weekday	30/01/2003	1500-1800	6	yyy	yyn	nnn	nnn	nnn	nnn	nnn	nnn
ealing	down town	crisis	weekday	30/01/2003	1500-1800	6	yyy	yyn	nnn	nnn	nnn	nnn	nnn	nnn
finchley	suburban	crisis	weekday	30/01/2003	1500-1800	6	yyy	yyn	nnn	nnn	nnn	nnn	nnn	nnn
barking	suburban	crisis	weekday	30/01/2003	1500-1800	6	yyy	yyn	nnn	nnn	nnn	nnn	nnn	nnn
maidenhead	provincial	crisis	weekday	30/01/2003	1500-1800	6	yyy	yyn	nnn	nnn	nnn	nnn	nnn	nnn
aylesbury	provincial	crisis	weekday	30/01/2003	1500-1800	6	yyy	yyn	nnn	nnn	nnn	nnn	nnn	nnn
luton	provincial	crisis	weekday	30/01/2003	1500-1800	6	yyy	yyn	nnn	nnn	nnn	nnn	nnn	nnn
chelmsford	provincial	crisis	weekday	30/01/2003	1500-1800	6	yyy	yyn	nnn	nnn	nnn	nnn	nnn	nnn
tilbury	provincial	crisis	weekday	30/01/2003	1500-1800	6	yyy	yyn	nnn	nnn	nnn	nnn	nnn	nnn

# Testing a Complex System

## Proof of Intelligence

Complexity Type	As Demonstrated in Scenario
Complex Data	Must identify learn & adapt filters to balance network usage
Complex Data	Call data, user data, performance data, is hierarchical & changes by time & by perspective
Complex Interactions	Impossibility of correctly predicting hardware failure or environmental conditions & possibility of seeing new trends

## **The Application Programs**

The intelligence cycle was demonstrated in three demonstrator programs

**CODA Red**

This shows response to 'threat' environmental conditions

**CODA Blue**

This shows response to the different types of system usage

**Coda Green**

This shows intelligent adaptation



# CODA Red

Objective	Critical Success Factors		
Coda Definitions	Identify pattern from: Range of measurable environmental conditions	Select from range of possible operating conditions	Apply run time variable from range of possible measurable operating values
Coda Red Example (identify) maintain minimum service under failure conditions	Detect threat dimensions	Threat = three base stations orange or one base station red	Adjust Contract filters Special filters Device filters

Each program is pre-set with slightly different objectives in order to show different aspects of the intelligence cycle

CODA Red shows how the systems BSC cells automatically divert calls when the system is busy

The screenshot displays the 'Monitoring Operations Layer - Base Station Call Processing with Preset Data' window. It features several key sections:

- Base Station Details:** Shows BS: 1007 (tottenham), Lines: 10, Blocks: 30, Type: provincial, Free: 5, Free: 18, Date: 16/09/2002, Danger: 6, Danger: 15, Timeband: 0900-1200, BS Status: online, Divert: 2, Recig? n, Mode: Manual, Errors: 9008.
- Previous Event Results:** Shows Caller id No: 142, Caller Tel: 07896554350, Service Type: ipeg, User Type: gold, Device Type: laptop, Start time: 10:13:33, End Time: 10:21:54, Duration: 501, Bandwidth: 3, Line No: 4.
- Error Report:** Shows Err Status: n, Err No: 0, Err Type: , Err Severity: 0, Usr Err Msg: No error message sent to user.
- BS Line Usage:** A table showing line usage for lines 0-9, with columns for Line, Online, and Callid.
- Incoming Event:** Shows Initiator: 07896554351, Service Type, User type, Device type, Make/Model, and Event type: lend.
- Control Panel:** Includes buttons for Pause Auto, Switch Mode, Next Manual, and an Event Clock showing 10:22:13.
- BS Call Log:** A table listing call records with columns for callid, caller, start time, end time, service type, dirhUsed, errStatus, timeBand, callDate, receiver, duration, device type, user type, bsNo, reconfig, errType, reconfig, errSever, reconfig, cstValue, and makeModel.
- BS Status Log:** A table showing base station status with columns for Date, TimeBand, Location, BSNo, Type, Nlines, LinesFree, NBlocks, and BlocksFree.


Each BSC cell has three possible operating conditions: red, yellow and green

The MSC decides which base station to divert calls to and keeps track of the overall system traffic

Monitoring Ops Layer - Mobile Switching Centre View

**MSC Details**

MSC ID: 11    Time Band: 0900-1200    Tot Line Capacity: 100    Reconfig Status: 0  
 MSC Name: CODA-TEL    Op Mode A: Online    Tot Bwidth Capacity: 300    Alert Condition: 0  
 Location: UK    Op Mode B: Ready    Tot Lines Free: 100  
 Status: Active    Error Status: 0    Tot Bwidth Free: 300



**Current Call Connection Log**

Call ID	Sender BSC	Receiver BSC	Rec Status	Err Status	Reconfig Status	Err Type	Reconfig Type	CSF Value
33	Tottenham	Covent Garden	ok	0	0	0	none	0

**MSC Connection History**

Date	Time	TimeBand	CallType	OrigBSC	SendBSC	RecBSC	UsrType	CallId
16/09/2002	10:01:10	0900-1200	auth	wimbledon	wimbledon	wimbledon	silver	79
16/09/2002	10:01:01	0900-1200	auth	covent garden	covent garden	covent garden	silver	151
16/09/2002	10:59:03	0900-1200	auth	UMTS	UMTS	UMTS	silver	152
16/09/2002	09:00:00	0900-1200	auth	cambridge	cambridge		silver	153
16/09/2002	09:00:00	0900-1200	auth	canterbury	canterbury		silver	154
16/09/2002	10:59:03	0900-1200	auth				gold	155

**User Identification Register**

UserType	UTOK	Subtype	TelNo	Password	UserName	AuthCode	DeviceType	MakeModel	BS	utran	Active	online	sms	voice	wap	mp3	fax
silver	0	gold24c	07896554	eba	abe	okabeok	laptop	Sony Viao	covent ga	y	y	y	y	y	y	n	y
gold	0	standard	07896554	demha	ahmed	okahmed	laptop	Dell Inspiri	cambridge	y	y	y	y	y	n	n	y
bronze	0	standard	07896554	neelia	aileen	okaleenol	handset	Bosch 12i	victoria	n	y	y	y	y	n	n	n
bronze	0	standard	07896554	ila	ali	okaliok	laptop	Dell Inspiri	covent ga	n	y	y	y	y	n	n	n
bronze	0	standard	07896554	nalla	allan	okallanok	laptop	Sony Viao	wimblebor	n	y	y	y	y	n	n	n
bronze	0	standard	07896554	yma	amy	okamyok	laptop	Sony Viao	canterburj	n	y	y	y	y	n	n	n

**BS Status Log**

Date	TimeBand	Location	BSNo	Type	Nlines	LinesFree	NBlocks	BlocksFree
16/09/2002	0900-1200	city ec1	123	down town	10	1	30	6
16/09/2002	0900-1200	covent garden	365	down town	10	2	30	7
16/09/2002	0900-1200	oxford st	459	down town	10	1	30	4
16/09/2002	0900-1200	victoria	925	down town	10	2	30	6
16/09/2002	0900-1200	cambridge	230	provincial	10	4	30	14
16/09/2002	0900-1200	canterbury	999	provincial	10	9	30	28
16/09/2002	0900-1200	edinburgh	121	provincial	10	1	30	5
16/09/2002	0900-1200	highbury	709	suburban	10	0	30	7
16/09/2002	0900-1200	tottenham	911	suburban	10	9	30	27
16/09/2002	0900-1200	wimbledon	847	suburban	10	2	30	6

Adjustments to special filters are managed by the MSC using CODA advice

# CODA Red shows how CODA manages if a base station 'fails'

**Select User**

◀ UIR ▶

View UIR

View Device

Name:

Contract:

My Tel:

Online:  UMTS

Call to:

Service Message

**Service Menu**

sms

voice

wap

fax

mp3

www

jpeg

video

**UMTS Scenario**

The GSM Base stations in the user's vicinity are close to failure. When the user attempts to send a call (providing if his contract is gold or silver and his device has UMTS capability) the failing BSC requests MSC to log user onto the UMTS BSC

**Special Filter**

special filter has key role in maximising OPPORTUNITIES for system and its users. it has key role of minimising THREATS to system and its users.

**Mob Dev Filters**

	c	d	sp
c=contract	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
d=device	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
s=special	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
NB special filter always overrides contract filter	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
mp3	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
www	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
jpeg	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
video	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Service chains (not shown) sent with new filters (see MSC screen)

Device:

Model:

BSC:

Tband:

UserType	UTOK	Subtype	TelNo	Passwor	UserNam	AuthCod	DeviceT	MakeMo	BS	utran	Active	online	sms	voice	wap	mp3	fax	jpeg	www	vid
silver	1	gold24c	0789655	eba	abe	okabeok	laptop	Dell Insp	UMTS	y	y	y	y	y	y	n	y	n	y	n
gold	0	standard	0789655	denha	ahmed	okahmec	laptop	Dell Insp	cambrid	y	y	y	y	y	n	y	y	y	y	n
bronze	0	standard	0789655	neelia	aileen	okaleeni	handset	Bosch 1;	victoria	n	y	y	y	n	n	n	n	n	n	n
bronze	0	standard	0789655	ila	ali	okalik	laptop	Dell Insp	covert g	n	y	y	y	n	n	n	n	n	n	n
bronze	0	standard	0789655	nalla	allan	okallanol	laptop	Sony Via	wimblede	n	y	y	y	n	n	n	n	n	n	n
bronze	0	standard	0789655	yma	amy	okamyok	laptop	Sony Via	canterbu	n	y	y	y	y	n	n	n	n	n	n
silver	0	standard	0789655	emna	annie															
dna	0	dna	0608765	dna	ADL	dna	dna	dna	dna	dna	dna	dna	dna	dna	dna	dna	dna	dna	dna	dna
silver	1	standard	0789655	arabrab	barbara	okbarbar	palntop	Samsung	wimblede	y	y	y	y	y	y	n	y	n	y	n

DeviceType	MakeModel	sms	GSM	UTR	voice	SSM1	UTR1	wap	SSM2	UTR2	fax	SSM3	UTR3	mp3	SSM4	UTR4	www	SSM5	UTR5	jpeg	SSM6	UTR6	video	SSM
handset	Dell Inspiron 2500	y	3456	0	y	4567	0	y	3456	0	y	3456	0	y	3456	1937	y	3456	0	y	4567	0	y	193
laptop	Dell Inspiron 5000	y	2345	2976	y	4567	2345	y	3456	1234	y	3456	1234	y	2345	3140	y	4567	4987	y	4567	2345	y	345
laptop	Sony Vaio 1500	y	3456	0	y	3456	0	y	3456	0	y	3745	0	y	3456	0	y	3456	0	y	3456	0	y	374
laptop	Sony Vaio 2000	y	4567	4987	y	1234	4987	y	1234	3140	y	4987	3456	y	4567	4987	y	1234	3140	y	6308	4987	y	498
palntop	Erikson 123	y	1234	0	y	3456	0	y	2345	0	y	2345	0	y	2345	0	y	4567	0	y	3456	0	n	
palntop	Erikson 175	y	3456	4008	y	4567	3456	y	3456	1937	y	3456	4987	y	3456	1937	y	3456	3745	y	4567	3090	y	345
palntop	Samsung 230	y	4567	0	y	3140	0	y	3745	0	y	3745	0	y	3745	0	y	1234	0	y	3456	0	n	
palntop	Samsung 231	y	3140	4987	y	2345	3456	y	4987	3745	y	4987	3456	y	4987	3745	y	4567	3745	y	4567	3456	n	

Only one rule is triggered in CAST – this is that silver users with device capability are reconfigured for UMTS services

This slide shows the MSC adjustment to user profiles in the event of a base station failure

CODA Layer 1 - Operations - MSC Role - User Authentication Process

**MSC Details**

MSC ID: 1 Op Mode A: Online Tot Line Capacity: 100  
 MSC Name: CODA-TEL Op Mode B: Ready Tot Bwidth Capcty: 300  
 Location: UK Error Stat: 0 Tot Lines Free: 100  
 Time Band: 0900-1200 Renfg Stat: 0 Tot Bwidth Free: 300  
 Alert Cond: 0 Status: Active

**User Requesting Authentication**

User Name: ahmed Make/Model: Dell Inspiron 5000  
 Pwd used: demha Tel No: 07896554306  
 User Type: gold BSC: GSM  
 User Message: Welcome Back AHMED!

**User Type Filters** By timeband, contract and day type (only week/day data shown)

usertype	daytype	timeband	sms	voice	wap	fax	mp3	www	jpeg	video
gold	weekday	0300-0600	y	y	y	y	y	y	y	y
gold	weekday	0600-0900	y	y	y	y	y	y	y	y
gold	weekday	0900-1200	y	y	y	y	n	y	y	n
lgold	weekday	1200-1500	y	y	y	y	y	y	y	n

**Current Call Connection Log**

Call ID: 179 Call Type: auth User Type: lgold  
 Date: 16/09/2002 Origin BSC: cambridge Renfg Stat: 1  
 Time: 09:01:02 Sender BSC: cambridge Fall Type: 0  
 Time Band: 0900-1200 Recvr BSC: cambridge Err Stat: 0

**MSC Authentication Log**

Date	TimeBand	TelNo	LoginTime	LastCont	LogoutTime	LocalBSC	AuthCode
16/09/2002	0900-1200	07896554348	10:59:03	10:59:03	10:59:03	UMTS	okavaok
16/09/2002	0900-1200	07896554322	09:00:00	09:00:00	09:00:00	covent garden	okabeok
16/09/2002	0900-1200	07896554322	10:59:03	10:59:03	10:59:03	UMTS	okabeok
16/09/2002	0900-1200	07896554306	09:01:02	09:01:02	09:01:02	cambridge	okahmedok

**BS Status Log**

Date	TimeBand	Location	BSNo	Type	Nlines	LinesFree	NBlocks	BlocksFree	linesDanger	Bw/Danger	Online	Active	AlertStatus	Diversion
16/09/2002	0900-1200	covent gard	365	down town	10	10	30	30	7	23 y	y	y	green	y
16/09/2002	0900-1200	oxford st	459	down town	10	10	30	30	7	23 y	y	y	green	y
16/09/2002	0900-1200	victoria	925	down town	10	10	30	30	7	23 y	y	y	green	y
16/09/2002	0900-1200	cambridge	230	provincial	10	9	30	28	7	23 y	y	y	green	y
16/09/2002	0900-1200	canterbury	999	provincial	10	9	30	28	7	23 y	y	y	green	y

**Device Filters** Make/model specific pointers to software routines within mobile device

DeviceType	MakeModel	sms	GSM	UTR	voice	SSM1	UTR1	wap	SSM2	UTR2	fax	SSM3	UTR3	mp3	SSM4	UTR4	www	SSM5	UTR5	jpeg	SSM6	UTR6	video	SSM7	UTR7
handset	Dell Inspiron 2501	y	3456	0 y	4567	0 y	3456	0 y	3456	0 y	3456	0 y	3456	0 y	3456	1937 y	3456	0 y	4567	0 y	4567	0 y	1937	0	
laptop	Dell Inspiron 5001	y	2345	2976 y	4567	2345 y	4567	4987 y	3456	1234 y	2345	3140 y	4567	4987 y	4567	2345 y	3456	1234 y	4567	2345 y	3456	1234 y	3456	1234	
laptop	Sony Vaio 1500	y	3456	0 y	3456	0 y	3456	0 y	3745	0 y	3456	0 y	3456	0 y	3456	0 y	3456	0 y	3456	0 y	3456	0 y	3745	0	
laptop	Sony Vaio 2000	y	4567	4987 y	1234	4987 y	1234	3140 y	4987	3456 y	4567	4987 y	1234	3140 y	6308	4987 y	4987	3456 y	4987	3456 y	4987	3456 y	4987	3456	
palmtop	Erikson 123	y	1234	0 y	3456	0 y	2345	0 y	2345	0 y	2345	0 y	4567	0 y	3456	0 n	0	0	0	0	0	0	0	0	

**User Identification Register** User device type and make/ model are unknown to the MSC until user attempts to authenticate

UserType	UTOK	Subtype	TelNo	Password	UserName	AuthCode	DeviceType	Make	BS	utr	Actn	onlin	sms	voic	wap	mp3	fax	jpeg
silver	1	gold24c	07896554322	eba	abe	okabeok	laptop	Dell	UMT	y	y	y	y	y	n	y	n	
gold	0	standard	07896554306	demha	ahmed	okahmedok	laptop	Dell	caml	y	y	y	y	y	n	y	y	
bronze	0	standard	07896554296	neelia	aileen	okailenok	handset	Bosc	vict	n	y	y	y	y	n	n	n	
bronze	0	standard	07896554374	ila	ali	okalio	laptop	Dell	cove	n	y	y	y	y	n	n	n	

This shows another possible scenario of network saturation

The screenshot displays a network management interface with several sections:

- Call Details:** BS: 1007 tottenham, Lines: 10, Blocks: 30, Type: provincial, Free: 4, Free: 16, Date: 16/09/2002, Timeband: 0900-1200, BS Status: BS, Divert: 2, Yellow: 1, Max: 10, Status: online, Recfg?: n, Mode: Auto, Errors: 1.
- Previous Event Results:** Caller id No: 158, Caller Tel: 07896554350, Service Type: mp3, User Type: gold, Device Type: laptop, Start time: 10:18:37, End Time: , Duration: , Bandwidth: 3, Line No: 0.
- Error Report:** Err Status: n, Err No: 0, Err Type: , Err Severity: 0, Usr Err Msg: No error message sent to user, Critical Success Factor: CSF Level: , **diverted**.
- BS Line Usage:** Table showing line status for lines 0-9.
- Base Station Special Filter:** A dialog box titled 'CODA/CAST' with a warning icon and the message: 'MSC has nowhere left to divert - network at full capacity - Reduce bs filters - log Gold and silver UMTS capable users onto UTM5 BSC'. It includes checkboxes for SMS and Voice filters and a Filter Stat: exp.
- BS Status Log:** A table listing various base stations and their status.

Line	Online	Callid
0	y	158
1	y	155
2	y	157
3	y	156
4	y	153
5	y	154
6	n	
7	n	
8	n	
9	n	

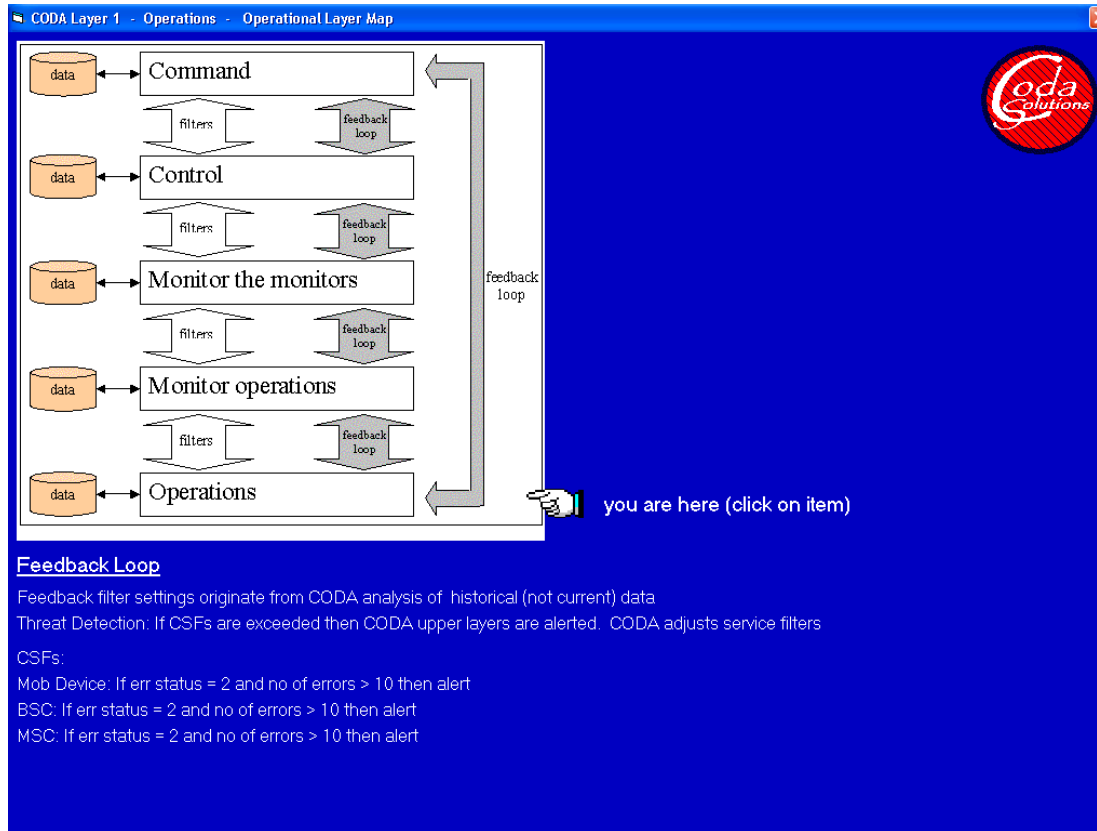
Date	TimeBand	Location	BSNo	Type	Nlines	LinesFree	NBlocks	BlocksFree
16/09/2002	0900-1200	city ec1	123	down town	10	1	30	6
16/09/2002	0900-1200	covent garden	365	down town	10	2	30	7
16/09/2002	0900-1200	oxford st.	459	down town	10	1	30	4
16/09/2002	0900-1200	victoria	925	down town	10	2	30	6
16/09/2002	0900-1200	cambridge	230	provincial	10	4	30	14
16/09/2002	0900-1200	canterbury	999	provincial	10	9	30	28
16/09/2002	0900-1200	edinburgh	121	provincial	10	1	30	5
16/09/2002	0900-1200	highbury	709	suburban	10	0	30	7
16/09/2002	0900-1200	tottenham	911	suburban	10	5	30	19
16/09/2002	0900-1200	wimbledon	842	suburban	10	7	30	6

The same rule has been triggered

# CODA Blue

Objective	Critical Success Factors		
Coda Definitions	Identify pattern from: Range of measurable environmental conditions	Select from range of possible operating conditions	Apply run time variable from range of possible measurable operating values
Coda Blue Example (learn) maintain balanced usage of lines and bandwidth	Threat opportunity normal	BSC status MSC status MS status	Contract filters Special filters Device filters

CODA Blue shows adjustment to special filters over time

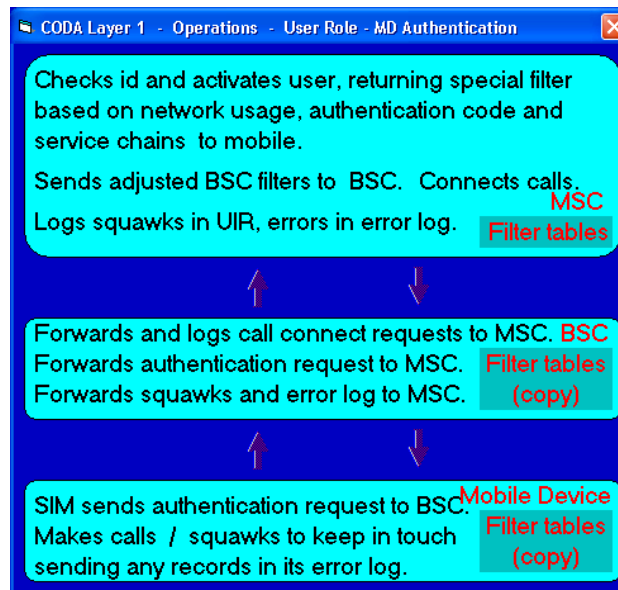


There are two types of feedback:

The feedback loop under threat, when emergency special filters are imposed,  
 The opportunity feedback, when special offer filters are imposed



# CODA Blue shows the normal feedback based on analysis of call patterns



Most adjustments are made in the initial authentication process

The user authenticates when he logs on to any compatible device

Name:

Contract:

Tel No:

Password:

On line?

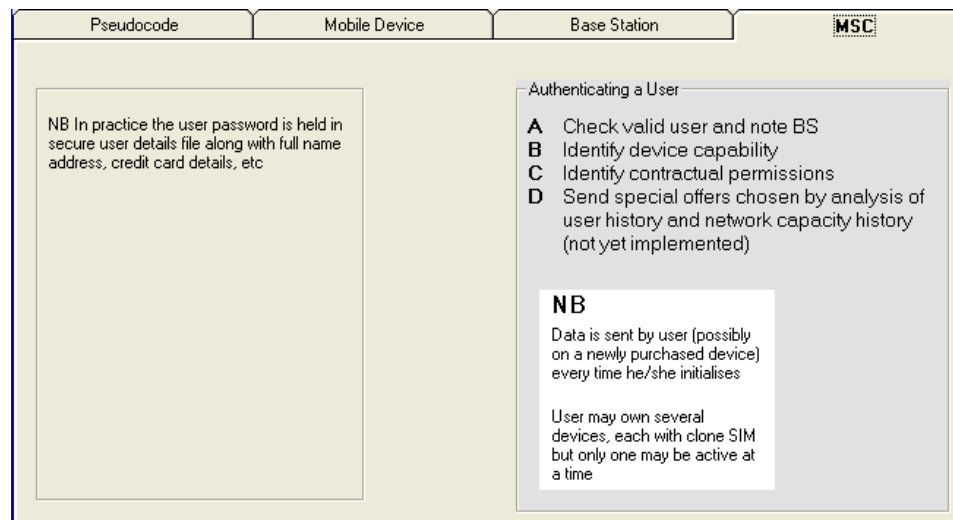
Navigation: [Back] [Left] [Right] [Forward]

**Keypad**

a b c d e f g h i j k l  
m n o p q r s t u v w x  
y z 0 1 2 3 4 5 6 7 8 9  
Space \* @ . \ # **Enter**

Only one device may be logged in by the same user at any given time

The system returns any special permissions, special offers, reductions, advice etc at the log in and at the beginning of a timeband



# An example of a special offer made within a timeband

My Name:	Sarah	Caller:	Jack
My Tel:	07896554291	Caller's Tel:	01 797455321
My Contract:	Bronze	Call Status:	Connected
Service now:	MP3	Call Type:	Incoming
		Call Time:	3min 22sec

**Service Message**

**Special Offer - Today only - WWW Available all day!**



The screenshot shows an MP3 player interface with a menu bar (File, View, Play, Tools, Help), a progress bar, and playback controls (play, pause, stop, previous, next). The metadata displayed is: Show: Musik; Clip: Plastique; Author: Placthman; Copyright: (blank). The status bar indicates 'Playing' and '06:56 / 13:03'. A white circle with 'MP3' is overlaid on the player.

**END CALL**



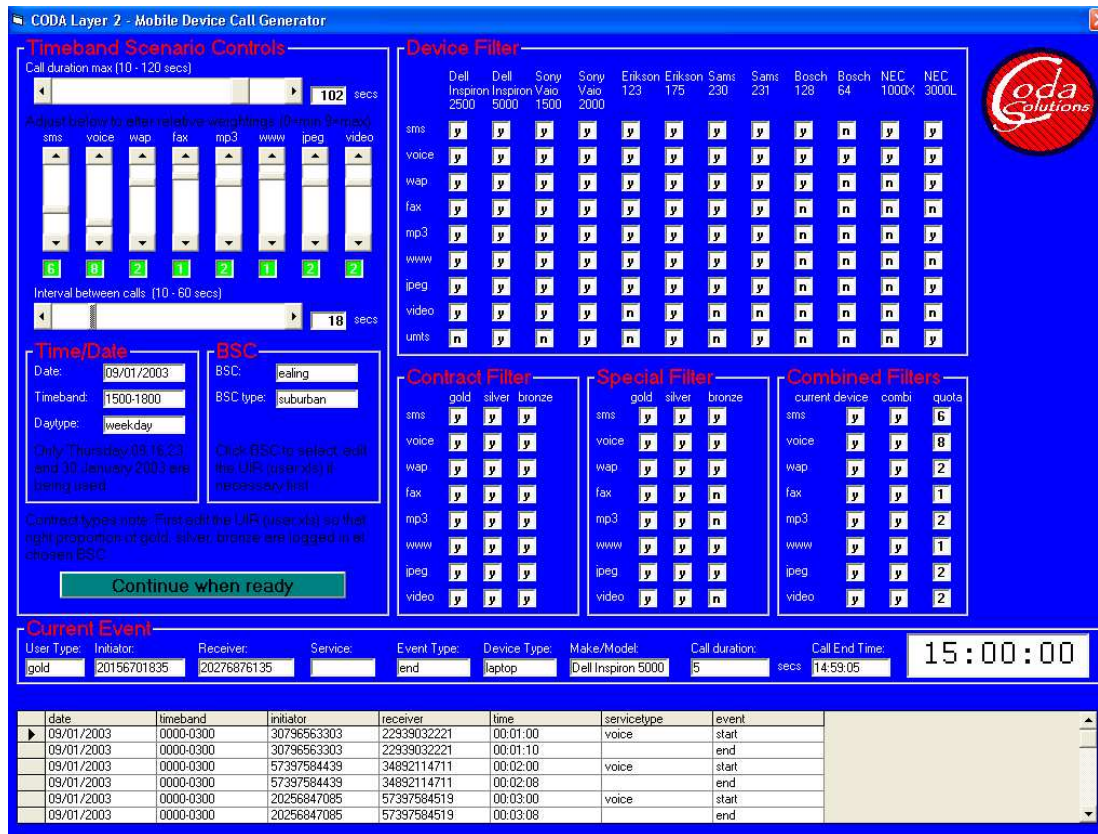
The logo for Coda Solutions, featuring the word 'Coda' in a stylized red font with 'Solutions' in a smaller black font below it, all within a red circular border.

# CODA Green

Objective	Critical Success Factors		
Coda Definitions	Identify pattern from: Range of measurable environmental conditions	Select from range of possible operating conditions	Apply run time variable from range of possible measurable operating values
Coda Green example (Adapt) modify behaviour according to trend	Detect clusters over time	Depending on Time Group location and forecast details	Adjust Contract filters Special filters Device filters

CODA green is designed to analyse trends to to adapt responses automatically

In order to do this ten active base stations were built each managing calls independently,



The MSC managed the ten base stations and 180 callers each making calls generated by the call generator shown above

# The MAC manages calls and applies special filters on the basis of CODA intelligent advice

The MSC is a 'cell', with a status log, failure log and filter settings, just like the BSC

The screenshot displays the MSC interface with the following details:

- MSC name:** CODA-TEL
- Bandwidth:** 300
- Lines:** 100
- Alert status:** (Green indicator)
- Location:** UK
- BW free:** 300
- Lines free:** 100
- Date:** 09/01/2003
- Connected:** 3577
- Active:** y
- BW Yellow:** 20
- Lines Yellow:** 6
- Day Type:** weekday
- Rejected:** 1469
- Online:** y
- BW red:** 10
- Lines red:** 3
- Timeband:** 1500-1800
- Diverted:** 16

**System Data Store** (Complete)

date	timeband	initiator	receiver	time	servicetype	event
09/01/2003	1500-1800	20711037191	80057712022	18:00:16		end
09/01/2003	1500-1800	80057712029	20056556585	18:00:18		end
09/01/2003	1500-1800	29076439765	80057712022	18:00:24		end
09/01/2003	1500-1800	80057712028	20176730885	18:00:24		end
09/01/2003	1500-1800	80057712036	80057712025	18:00:25		end
09/01/2003	1500-1800	94196554548	21899301207	18:00:27		end
09/01/2003	1500-1800	80057712025	94196554452	18:00:29		end
09/01/2003	1500-1800	20176730885	85307772018	18:00:33		end
09/01/2003	1500-1800	23236098185	94196554548	18:00:35		end
09/01/2003	1500-1800	30796563292	30796563302	18:00:39		end
09/01/2003	1500-1800	22196367211	34892131311	18:00:42		end
09/01/2003	1500-1800	23533164185	ISP	18:00:44		end
09/01/2003	1500-1800	29076439754	20711037191	18:00:46		end
09/01/2003	1500-1800	80057712031	34892121351	18:00:50		end
09/01/2003	1500-1800	74696554521	57397584379	18:00:56		end
09/01/2003	1500-1800	21453702201	57397584679	18:01:01		end
09/01/2003	1500-1800	85307772017	20859570193	18:01:02		end
09/01/2003	1500-1800	29076439759	29076439757	18:01:04		end
09/01/2003	1500-1800	85307772011	55196554494	18:01:19		end

**Special Filter**

Free lines: 24  
Free bandwidth: 72

	sms	voice	wap	fax	mp3	www	jpeg	video
Gold	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Silver	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Bronze	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

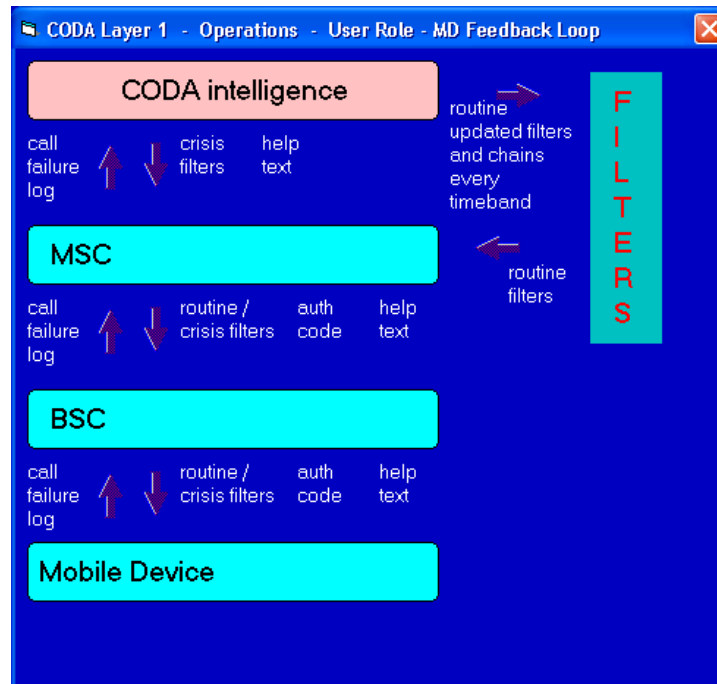
Blocks: 1 3 2 3 5 4 4 6

Successful calls are logged here

The special filters are shown here

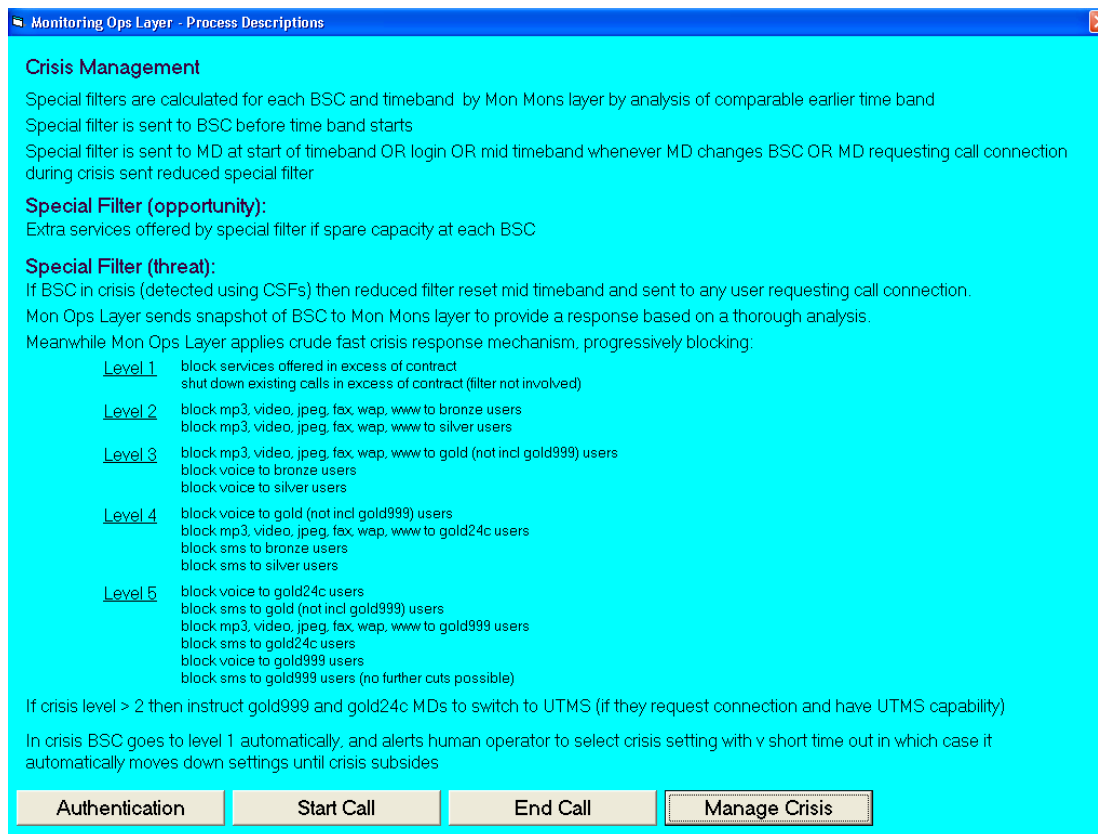
Filter settings are decided by intelligence cells at the higher layers

This diagram shows the flow of intelligence and how it can be delivered transparently





# The system is able to respond to non linear waves of calls effectively by imposing crisis filters



**Crisis Management**

Special filters are calculated for each BSC and timeband by Mon Mons layer by analysis of comparable earlier time band  
Special filter is sent to BSC before time band starts  
Special filter is sent to MD at start of timeband OR login OR mid timeband whenever MD changes BSC OR MD requesting call connection during crisis sent reduced special filter

**Special Filter (opportunity):**  
Extra services offered by special filter if spare capacity at each BSC

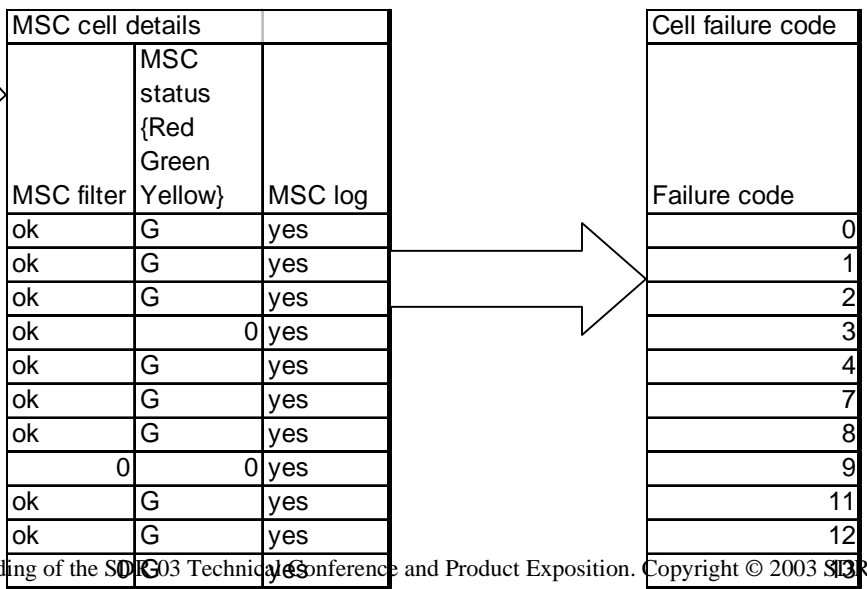
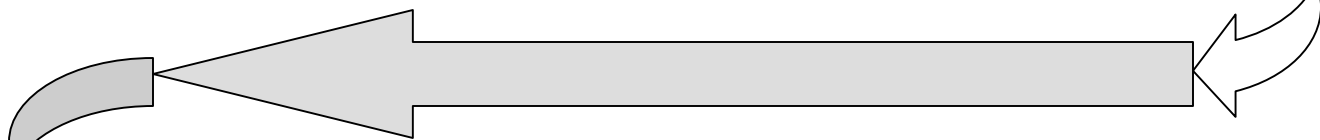
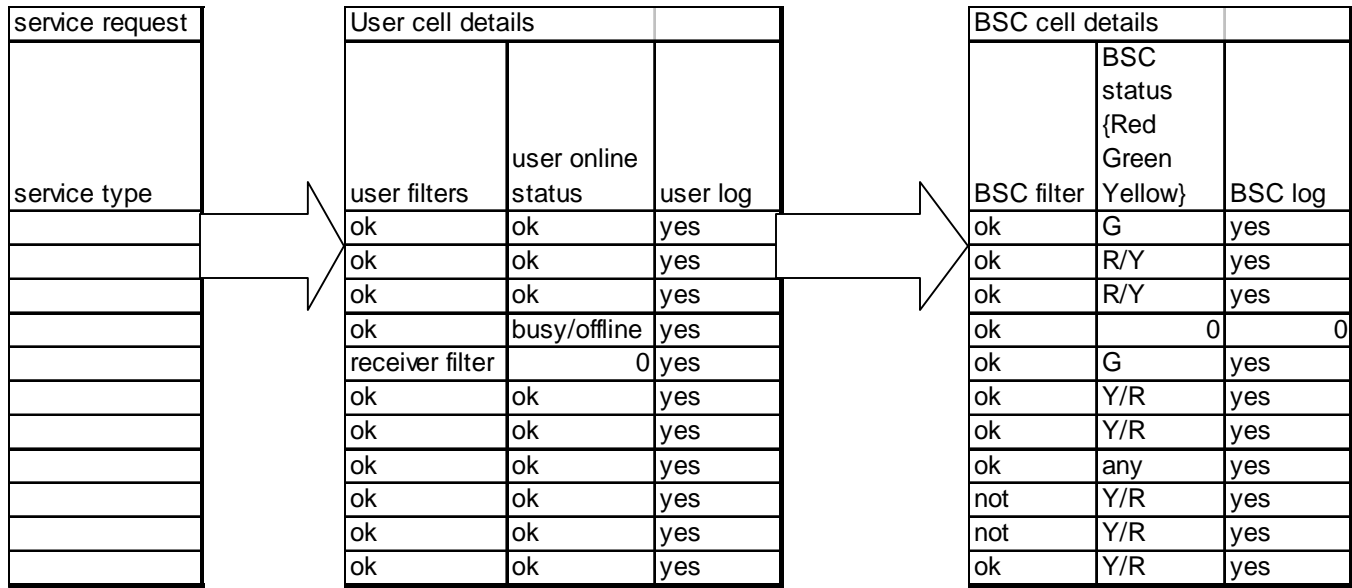
**Special Filter (threat):**  
If BSC in crisis (detected using CSFs) then reduced filter reset mid timeband and sent to any user requesting call connection.  
Mon Ops Layer sends snapshot of BSC to Mon Mons layer to provide a response based on a thorough analysis.  
Meanwhile Mon Ops Layer applies crude fast crisis response mechanism, progressively blocking:

- Level 1 block services offered in excess of contract  
shut down existing calls in excess of contract (filter not involved)
- Level 2 block mp3, video, jpeg, fax, wap, www to bronze users  
block mp3, video, jpeg, fax, wap, www to silver users
- Level 3 block mp3, video, jpeg, fax, wap, www to gold (not incl gold999) users  
block voice to bronze users  
block voice to silver users
- Level 4 block voice to gold (not incl gold999) users  
block mp3, video, jpeg, fax, wap, www to gold24c users  
block sms to bronze users  
block sms to silver users
- Level 5 block voice to gold24c users  
block sms to gold (not incl gold999) users  
block mp3, video, jpeg, fax, wap, www to gold999 users  
block sms to gold24c users  
block voice to gold999 users  
block sms to gold999 users (no further cuts possible)

If crisis level > 2 then instruct gold999 and gold24c MDs to switch to UTMS (if they request connection and have UTMS capability)  
In crisis BSC goes to level 1 automatically, and alerts human operator to select crisis setting with v short time out in which case it automatically moves down settings until crisis subsides

Authentication    Start Call    End Call    Manage Crisis

Crisis filters ensure that users get services albeit reduced to voice and sms for many – we have assumed that this is preferable to total loss of service –privileged users retain all services



# CODA Green Adaptive Response

The CODA Green responses are based on complex data analysis which allows the system to make predictions on the data.

Available green 16/01/2003 city	Max used%		special filter			
	lines	bw	lines	bw	Larger revision	
city	18	68	61.1%	48.5%	61.1%	Expand
westend	18	68	61.1%	50.0%	61.1%	Expand
aylesbury	7	35	85.7%	60.0%	85.7%	Expand
chelmsford	7	35	100.0%	62.9%	100.0%	No change
luton	7	35	100.0%	65.7%	100.0%	No change
maidenhead	7	35	100.0%	65.7%	100.0%	No change
tilbury	7	35	100.0%	60.0%	100.0%	No change
barking	12	50	91.7%	76.0%	91.7%	Expand
ealing	12	50	91.7%	78.0%	91.7%	Expand
finchley	12	50	91.7%	76.0%	91.7%	Expand
<b>Recommendation:</b>	alter special filters as suggested					

Recommendations are based on analysis by usage, comparison and forecasting cells.

Analysis is carried out on call data which is structured carefully to ensure that only mission critical data reaches the intelligence cells

	A	B	C	D	E	F	G
1	date	timeband	initiator	receiver	time	servicetype	event
2	09/01/2003	1500-1800	57397584679	94196554116	15:00:14	video	start
3	09/01/2003	1500-1800	20036527535	29076439762	15:00:15	jpeg	start
4	09/01/2003	1500-1800	57397584519	80057712027	15:00:17	voice	start
5	09/01/2003	1500-1800	34892127991	23533164185	15:00:18	jpeg	start
6	09/01/2003	1500-1800	20265438185	30796563288	15:00:19	jpeg	start
7	09/01/2003	1500-1800	34892124671	30796563288	15:00:20	video	start
8	09/01/2003	1500-1800	85307772014	85307772016	15:00:21	jpeg	start
9	09/01/2003	1500-1800	63636907657	29076439756	15:00:22	voice	start
10	09/01/2003	1500-1800	85307772006	20136672785	15:00:23	voice	start
11	09/01/2003	1500-1800	20056556585	57397584359	15:00:24	video	start
12	09/01/2003	1500-1800	63636907655	30796563301	15:00:28	jpeg	start
13	09/01/2003	1500-1800	21602235203	ISP	15:00:30	wap	start
14	09/01/2003	1500-1800	20136672785	80057712026	15:00:34	voice	start
15	09/01/2003	1500-1800	34892134631	85307772013	15:00:36	video	start
16	09/01/2003	1500-1800	57397584519	80057712027	15:00:36		end
17	09/01/2003	1500-1800	17896554427	34892141271	15:00:38	voice	start
18	09/01/2003	1500-1800	63636907647	34892141271	15:00:40	jpeg	start
19	09/01/2003	1500-1800	29076439757	20116905185	15:00:42	voice	start
20	09/01/2003	1500-1800	30796563288	23087565223	15:00:42	voice	start
21	09/01/2003	1500-1800	63636907652	34892151231	15:00:44	voice	start
22	09/01/2003	1500-1800	29076439763	17896554431	15:00:45	video	start
23	09/01/2003	1500-1800	63636907647	34892141271	15:00:45		end
24	09/01/2003	1500-1800	30796563302	42196554476	15:00:46	voice	start
25	09/01/2003	1500-1800	85307772006	20136672785	15:00:46		end
26	09/01/2003	1500-1800	80057712022	29076439754	15:00:48	jpeg	start
27	09/01/2003	1500-1800	85307772014	85307772016	15:00:50		end
28	09/01/2003	1500-1800	42196554476	94196554116	15:00:51	jpeg	start
29	09/01/2003	1500-1800	20036527535	29076439762	15:00:52		end
30	09/01/2003	1500-1800	85307772009	20176730885	15:00:54	voice	start
31	09/01/2003	1500-1800	80057712034	ISP	15:00:56	www	start
32	09/01/2003	1500-1800	20056556585	57397584359	15:00:56		end
33	09/01/2003	1500-1800	20236818035	34892137951	15:00:57	jpeg	start
34	09/01/2003	1500-1800	20265438185	30796563288	15:00:57		end
35	09/01/2003	1500-1800	57397584389	34892137951	15:01:00	video	start
36	09/01/2003	1500-1800	63636907646	ISP	15:01:00	www	start
37	09/01/2003	1500-1800	63636907652	34892151231	15:01:02		end
38	09/01/2003	1500-1800	34892141271	29076439756	15:01:03	video	start

CODA is able to deal with vast amounts of data by using ‘forgetting’ algorithms based on cognitive models.

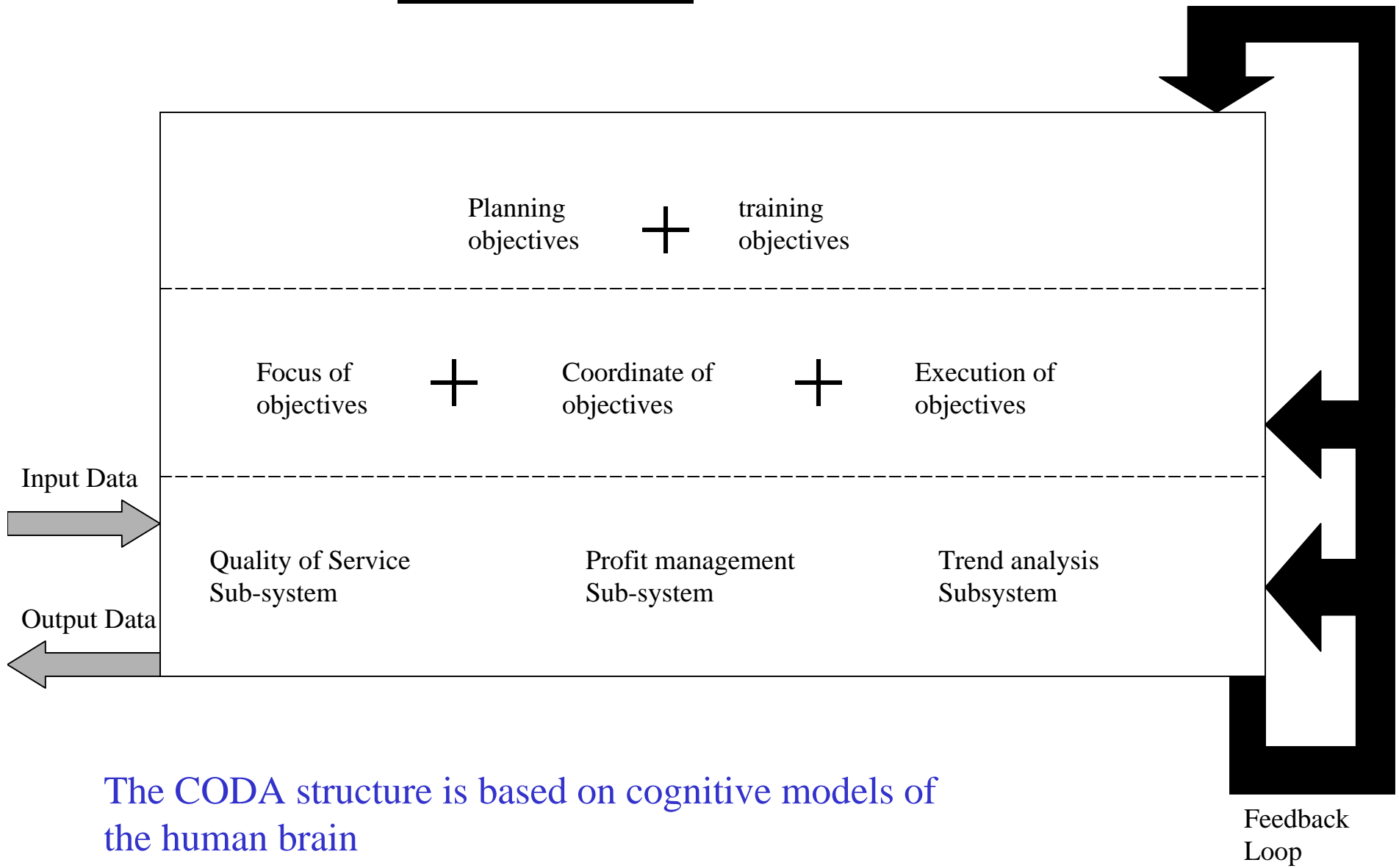
## Conclusions and Future Work

The CODA concept of automated response in an adaptive intelligence cycle has been successfully demonstrated and proved in so far as it is possible to show a complex system response

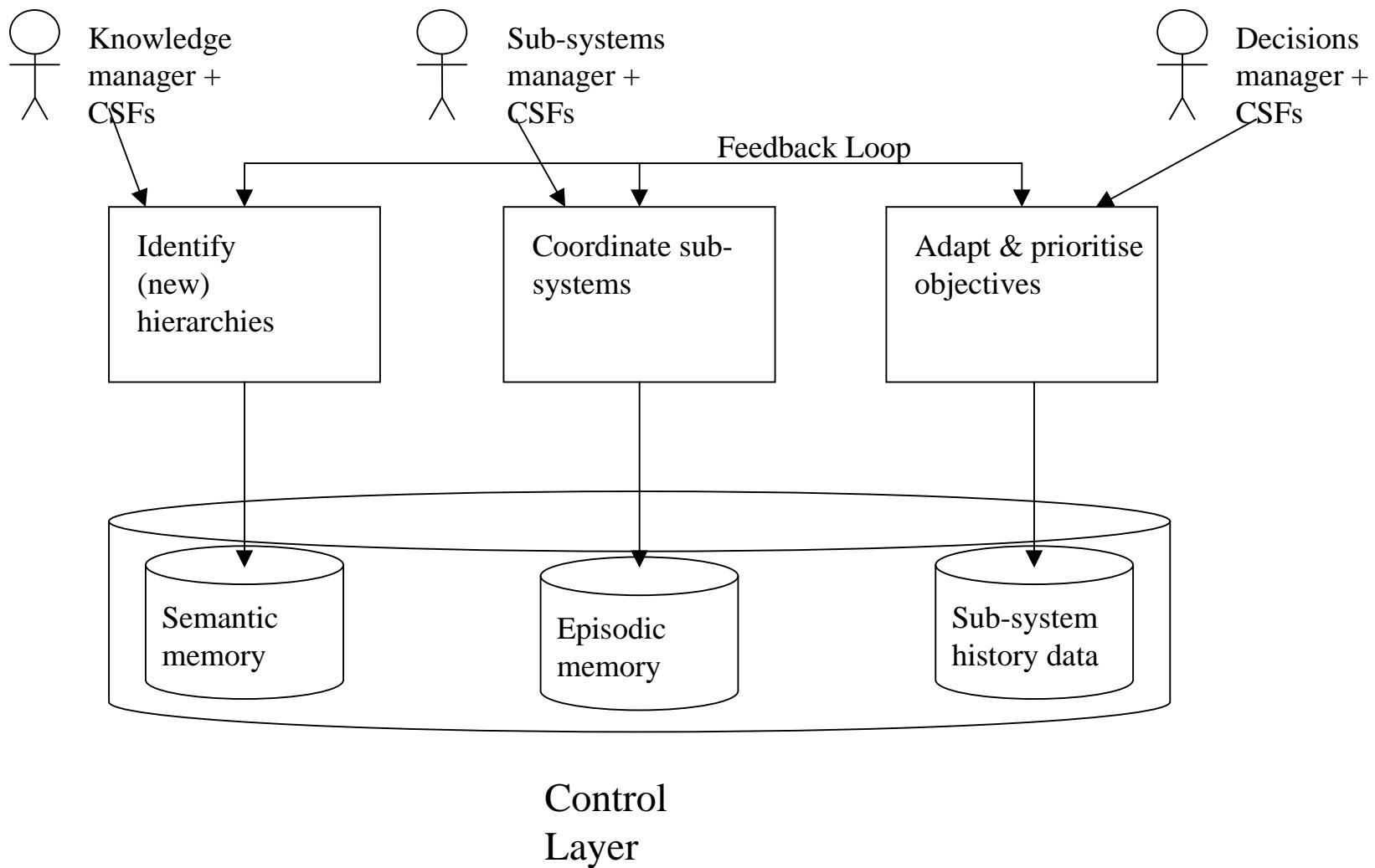
Further work involves applying CODA to real systems such as third generation mobile networks

It involves adding more sub-systems and co-ordinating them using the higher layers.

## Virtual Map Of Brain



The CODA structure is based on cognitive models of the human brain



At the higher command and control layers, CODA should be capable of simple speech based interactions

# Acknowledgements

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Nonetheless only the authors are responsible for the views expressed here