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

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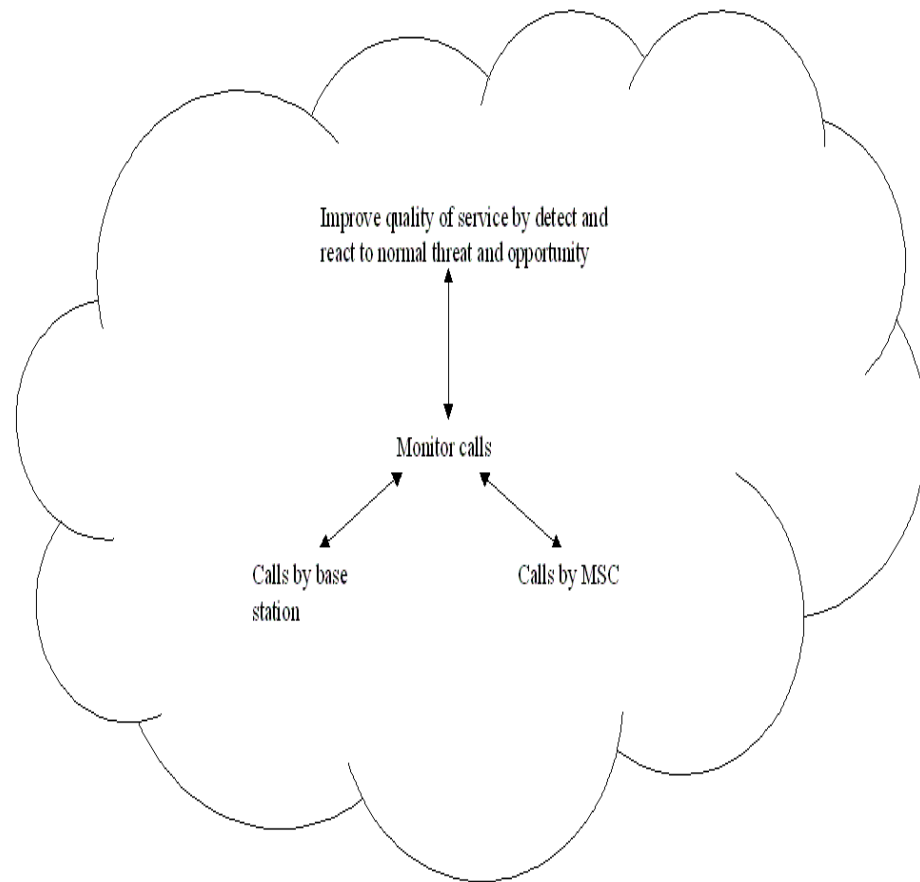# What we will cover:

Aims of the CAST project

CODA in the CAST project

An overview of CODA Intelligence
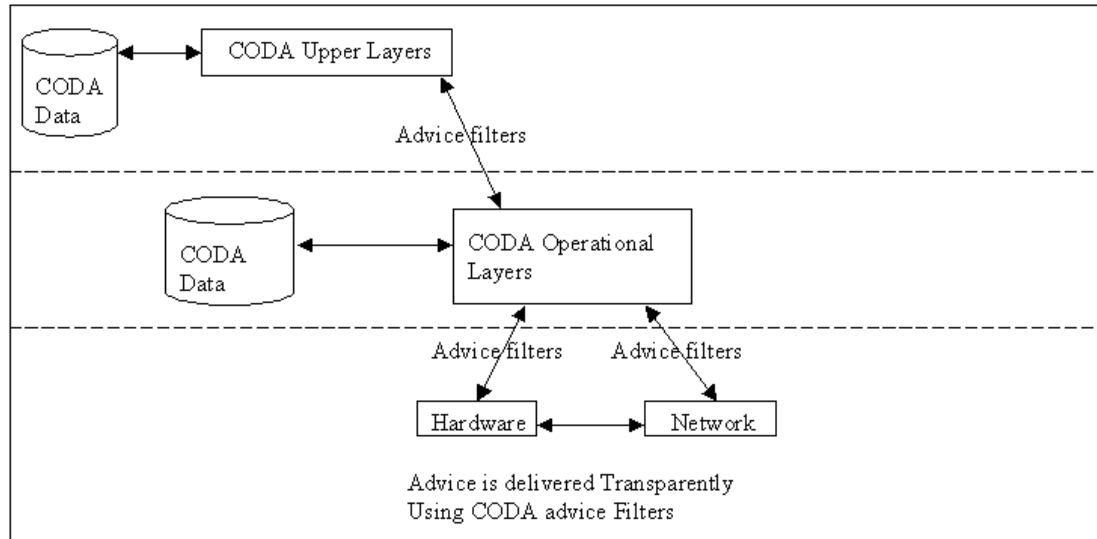
The CODA Sub-system

The Application Programs

Mobile phone Subsystem

Environmental variables

Improve quality of service by detect and react to normal threat and opportunity

Monitor calls

Calls by base station

Calls by MSC

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.
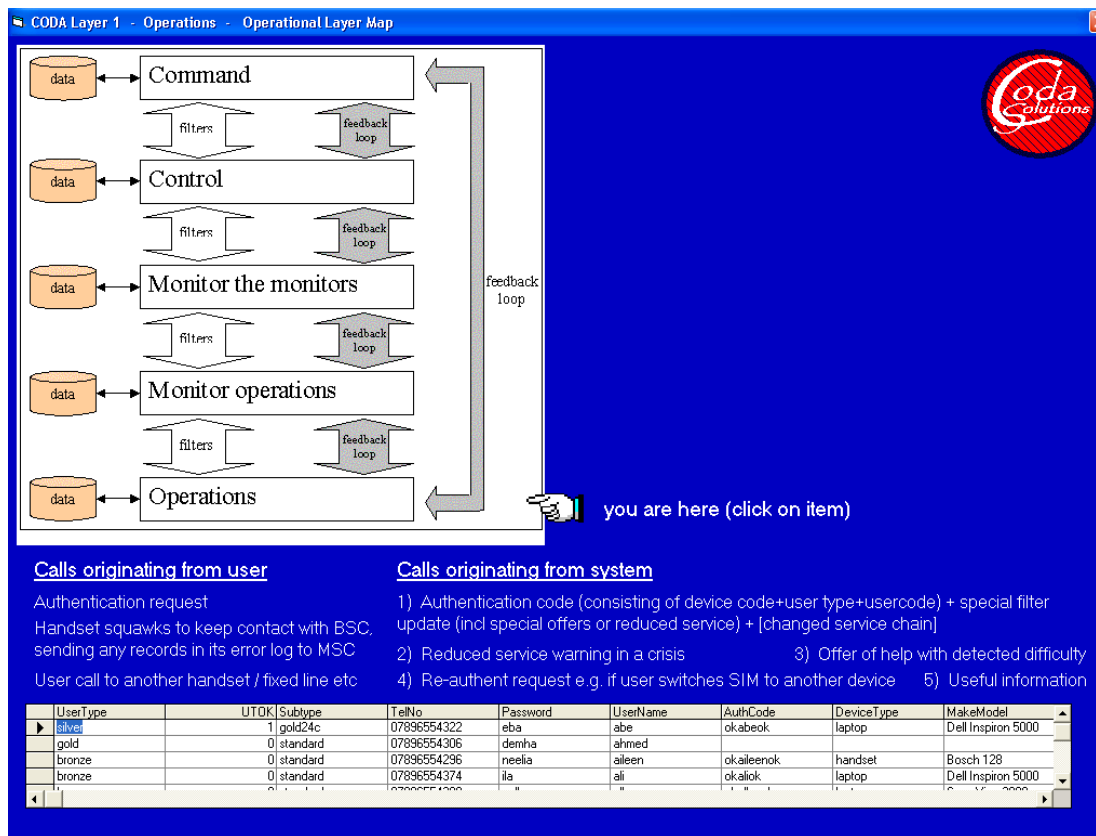

The aim of the intelligence system was to deliver the best quality of service under a variety of environmental conditions.

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.

CODA Layer 1 - Operations - Operational Layer Map

Command

filters | feedback loop

Control

filters | feedback loop

Monitor the monitors

filters | feedback loop

Monitor operations

filters | feedback loop

Operations

feedback loop

data

you are here (click on item)

Calls originating from user

Authentication request
Handset squawks to keep contact with BSC, sending any records in its error log to MSC
User call to another handset / fixed line etc

Calls originating from system

1) Authentication code (consisting of device code+user type+usercode) + special filter update (incl special offers or reduced service) + [changed service chain]

2) Reduced service warning in a crisis   3) Offer of help with detected difficulty

4) Re-authent request e.g. if user switches SIM to another device   5) Useful information

UserType	UTOK	Subtype	TelNo	Password	UserName	AuthCode	DeviceType	MakeModel
silver	1	gold24c	07896554322	eba	abe	okabeok	laptop	Dell Inspiron 5000
gold	0	standard	07896554306	demha	ahmed			
bronze	0	standard	07896554296	neelia	aileen	okaileenok	handset	Bosch 128
bronze	0	standard	07896554374	ila	ali	okaliok	laptop	Dell Inspiron 5000

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

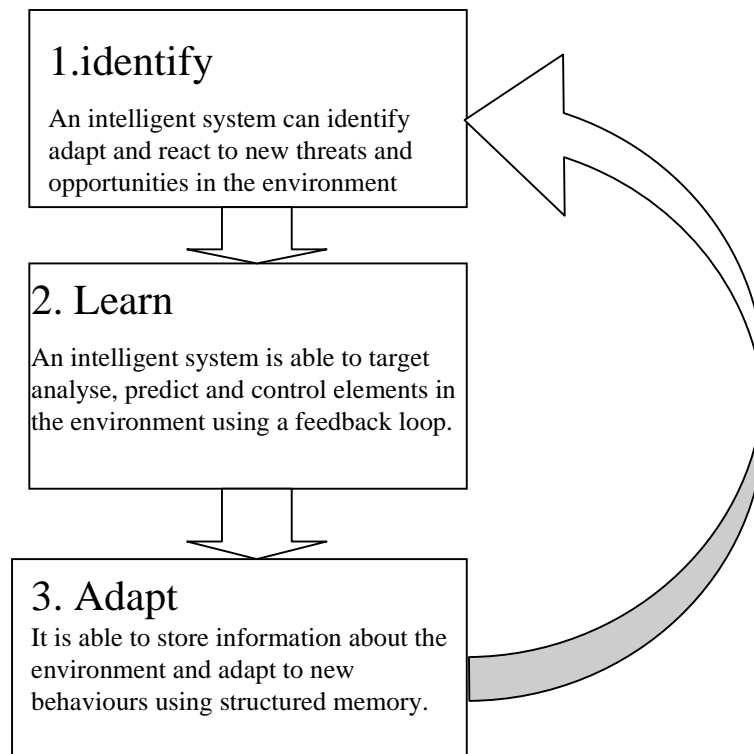This overview shows the sub-system constructed for the CAST project
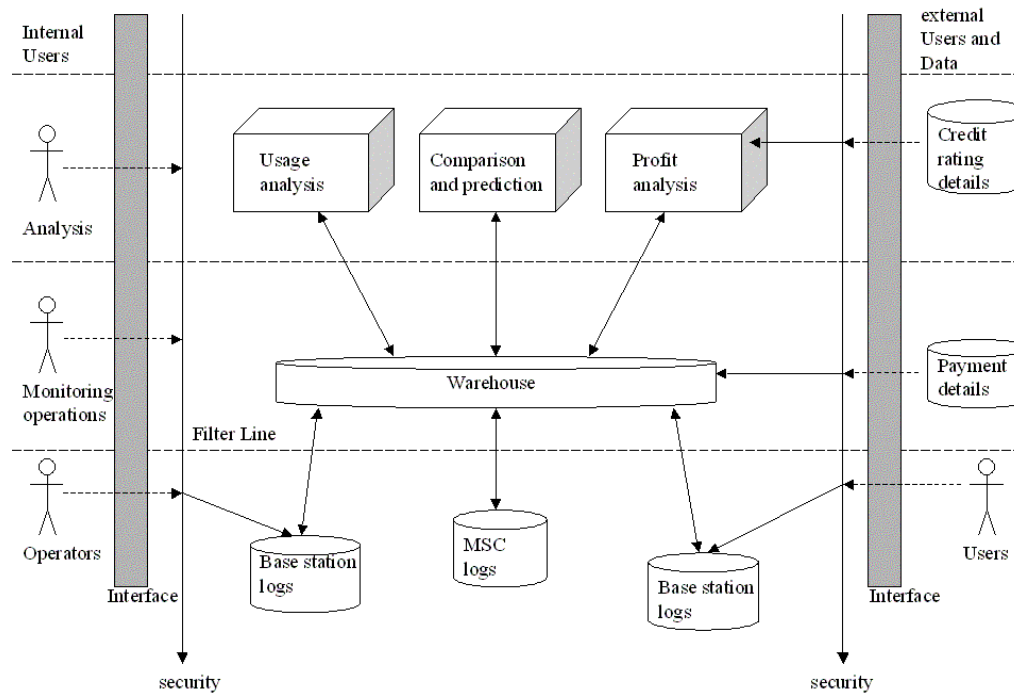
Component cells in the sub-system co-operate to meet an objective

A CODA Sub-system

The Intelligence Cycle

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

1.identify

An intelligent system can identify adapt and react to new threats and opportunities in the environment

2. Learn

An intelligent system is able to target analyse, predict and control elements in the environment using a feedback loop.

3. Adapt

It is able to store information about the environment and adapt to new behaviours using structured memory.

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

Feedback Loop

Filters

Input

Task List

Output

Status Log

Current Status Log

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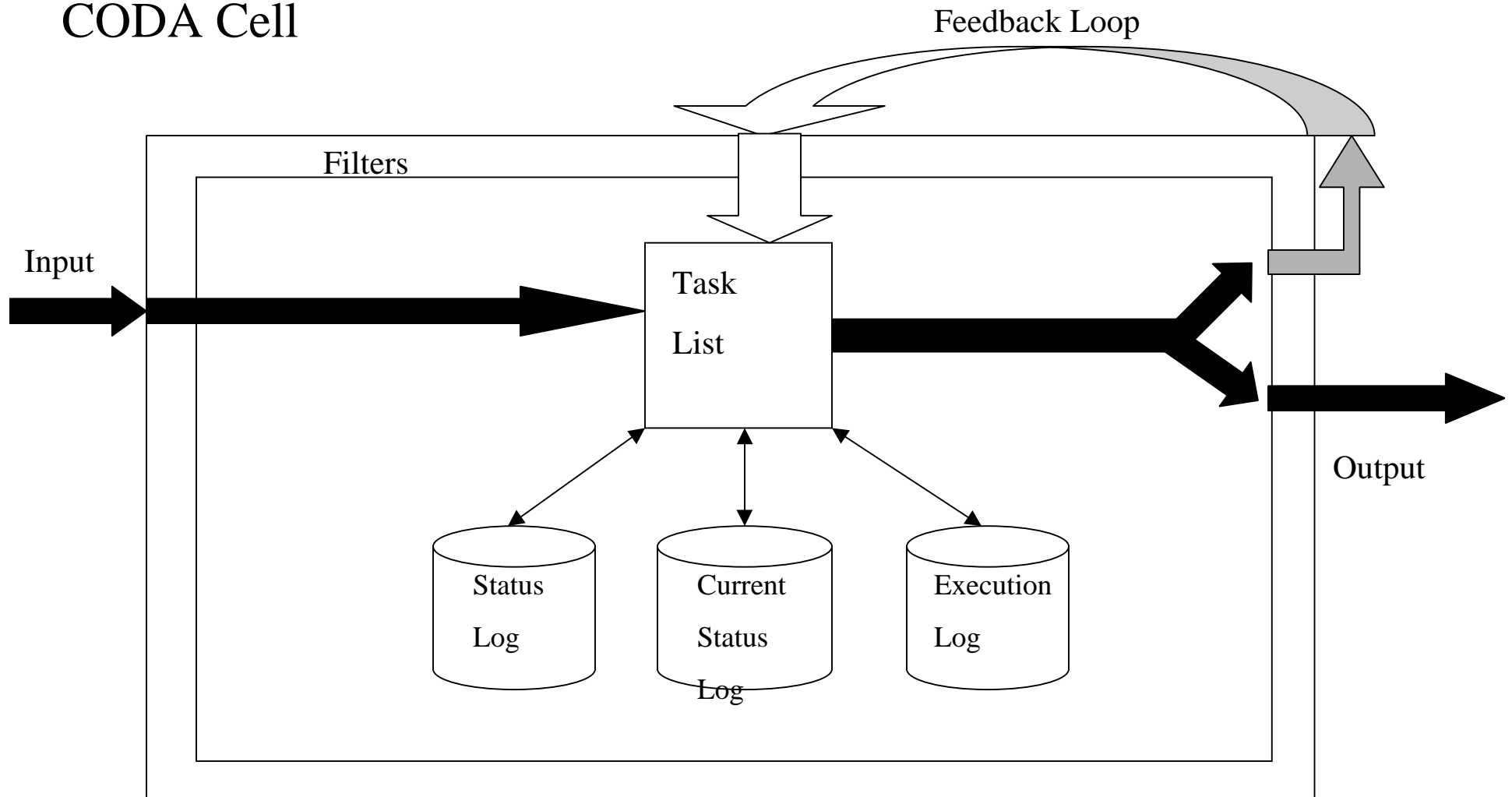
CODA Cells are based on organic systems. They are pre-set with operational parameters known as critical success factors and operate semi-autonomously unless they cannot meet operating tolerances.

This is an implementation of a CODA Cell in the CAST scenario
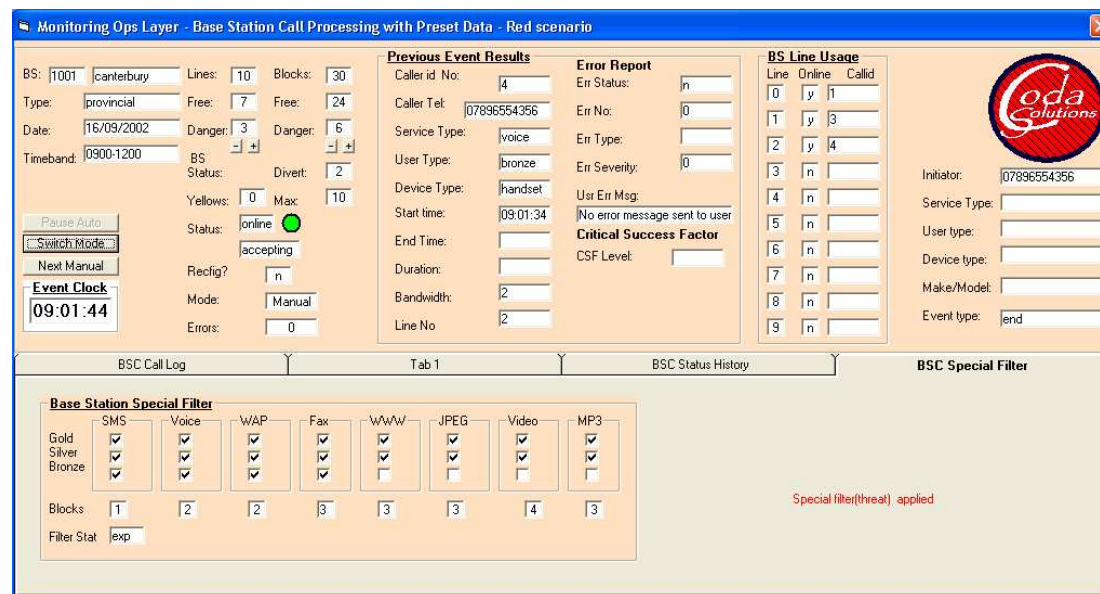
The BSC cell filters and critical success factors can be viewed and adjusted by an operator as the system manages calls. Otherwise adjustment is fully automated

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 diverts 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		
service type	user filters	user online 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 filters	BSC status {Red Green Yellow}	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 filters	MSC status {Red Green Yellow}	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

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

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

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

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

This shows another possible scenario of network saturation

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
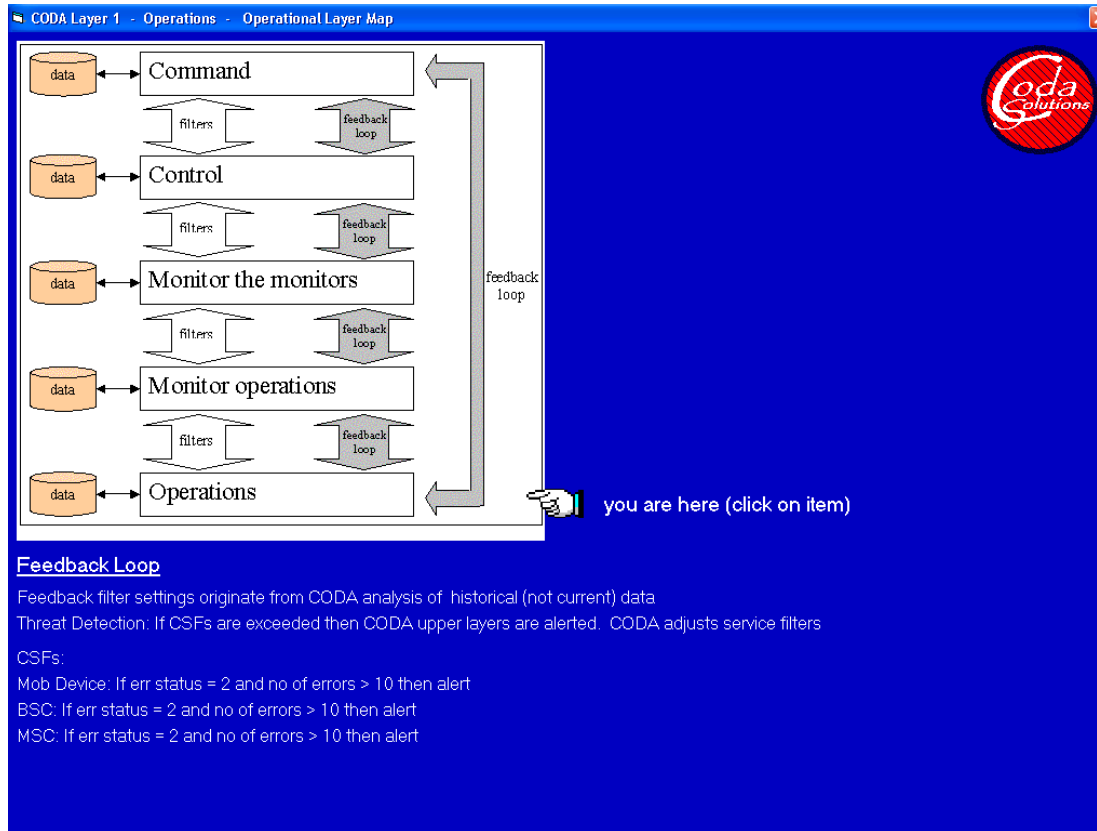
There are two types of feedback:

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
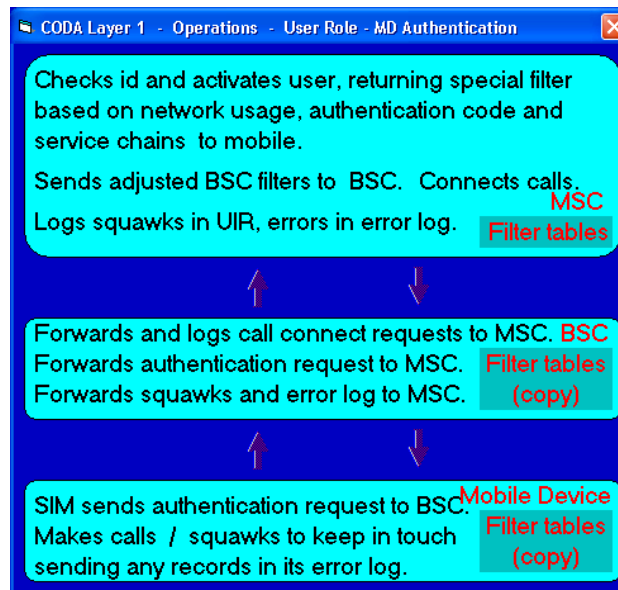
Most adjustments are made in the initial authentication process

The user authenticates when he logs on to any compatible device

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

Pseudocode	Mobile Device	Base Station	MSC

NB In practice the user password is held in secure user details file along with full name address, credit card details, etc

Authenticating a User

A Check valid user and note BS
B Identify device capability
C Identify contractual permissions
D Send special offers chosen by analysis of user history and network capacity history (not yet implemented)

NB

Data is sent by user (possibly on a newly purchased device) every time he/she initialises

User may own several devices, each with clone SIM but only one may be active at a time

An example of a special offer made within a timeband

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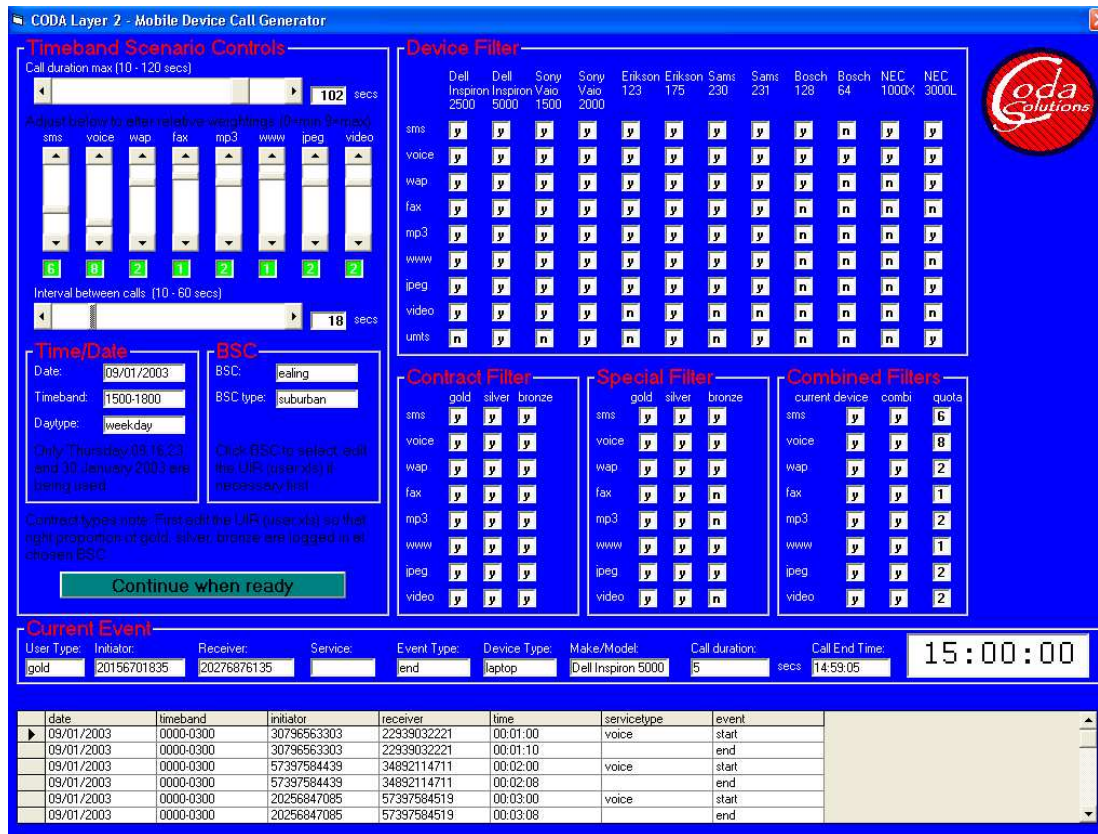
The MSC managed the ten base stations and 180 callers each making calls generated by the call generator shown above

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

Successful calls are logged here

The special filters are shown here
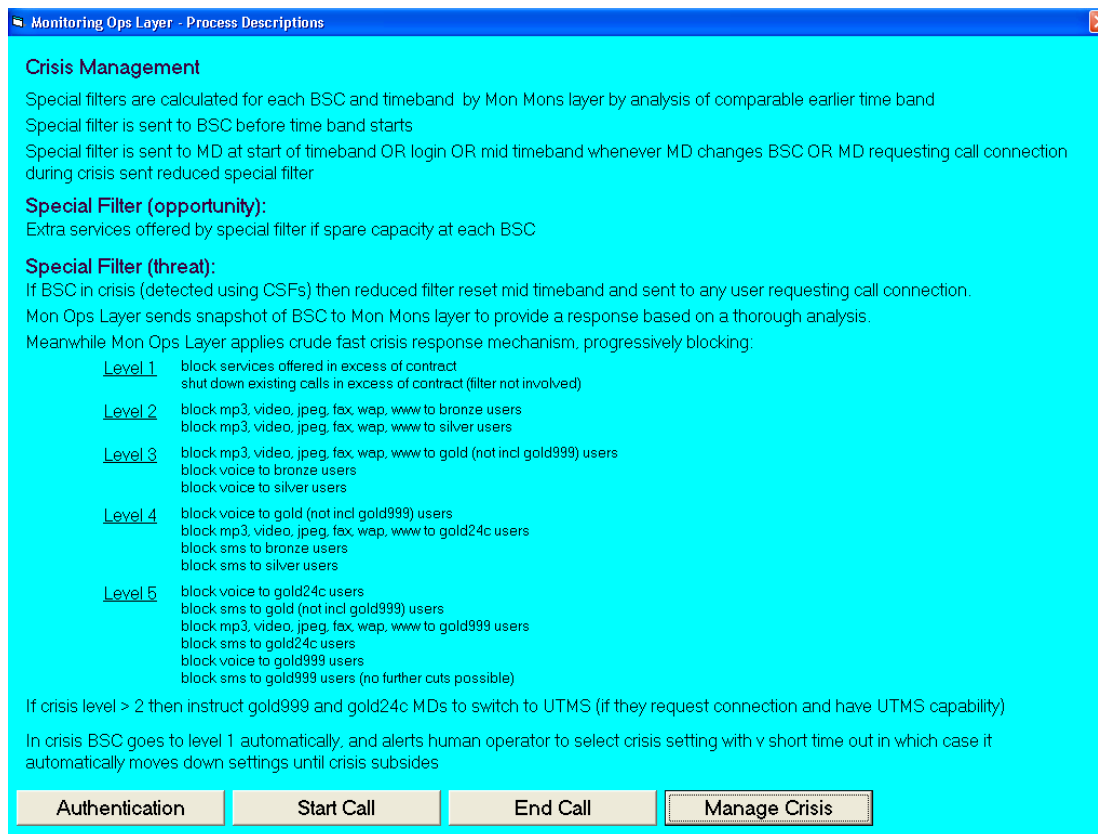
Filter settings are decided by intelligence cells at the higher layers

This diagram shows the flow iof intelligence and how it can be delivered transparently
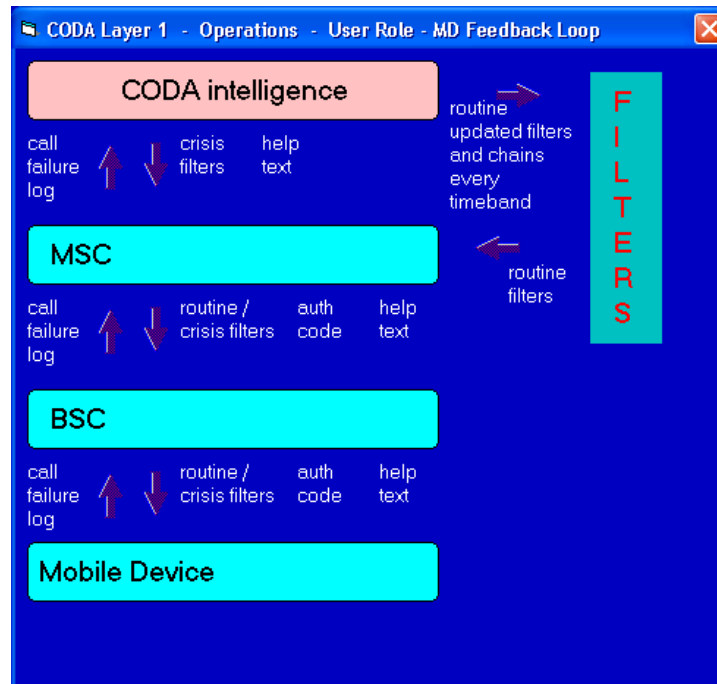
The system is able to respond to non linear waves of calls effectively by imposing crisis filters

Monitoring Ops Layer - Process Descriptions

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, 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

service request
service type

User cell details		
user filters	user online status	user log
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 filter	BSC status {Red Green Yellow}	BSC log
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

MSC cell details		
MSC filter	MSC status {Red Green Yellow}	MSC log
ok	G	yes
ok	G	yes
ok	G	yes
ok	0	yes
ok	G	yes
ok	G	yes
ok	G	yes
0	0	yes
ok	G	yes
ok	G	yes
ok	G	yes

Cell failure code
Failure code
0
1
2
3
4
7
8
9
11
12

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	lines	bw	Max used% lines	bw	special filter 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
Recommendation:			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 suing 'forgetting' algorithms based on cognitive models.
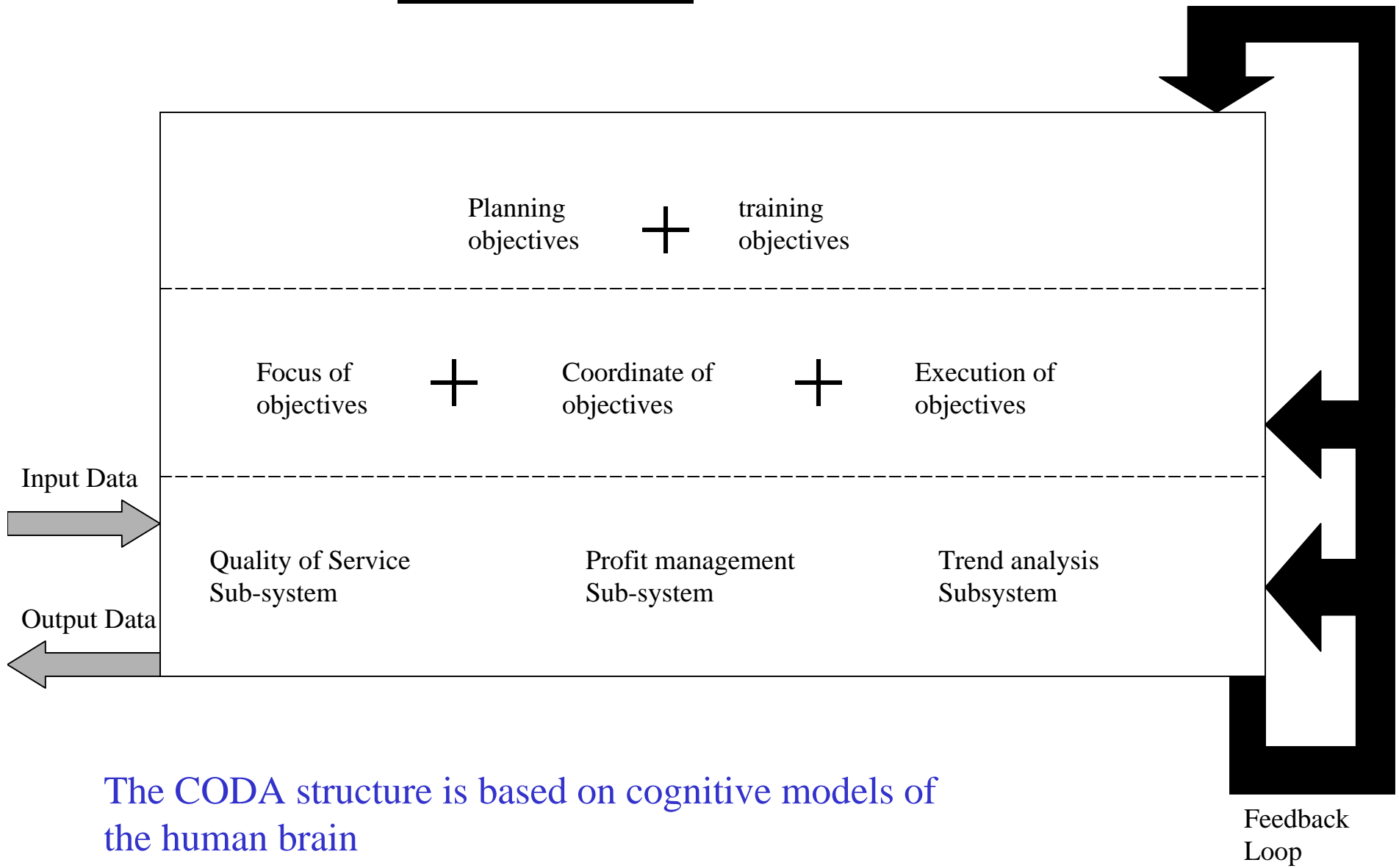
Conclusions and Future Work

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

Planning objectives   **+**   training objectives

- -

Focus of objectives   **+**   Coordinate of objectives   **+**   Execution of objectives

- -

Input Data

Quality of Service Sub-system   Profit management Sub-system   Trend analysis Subsystem

Output Data

Feedback Loop

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

Knowledge manager + CSFs

Sub-systems manager + CSFs

Decisions manager + CSFs

Feedback Loop

Identify (new) hierarchies

Coordinate sub-systems

Adapt & prioritise objectives

Semantic memory

Episodic memory

Sub-system history data
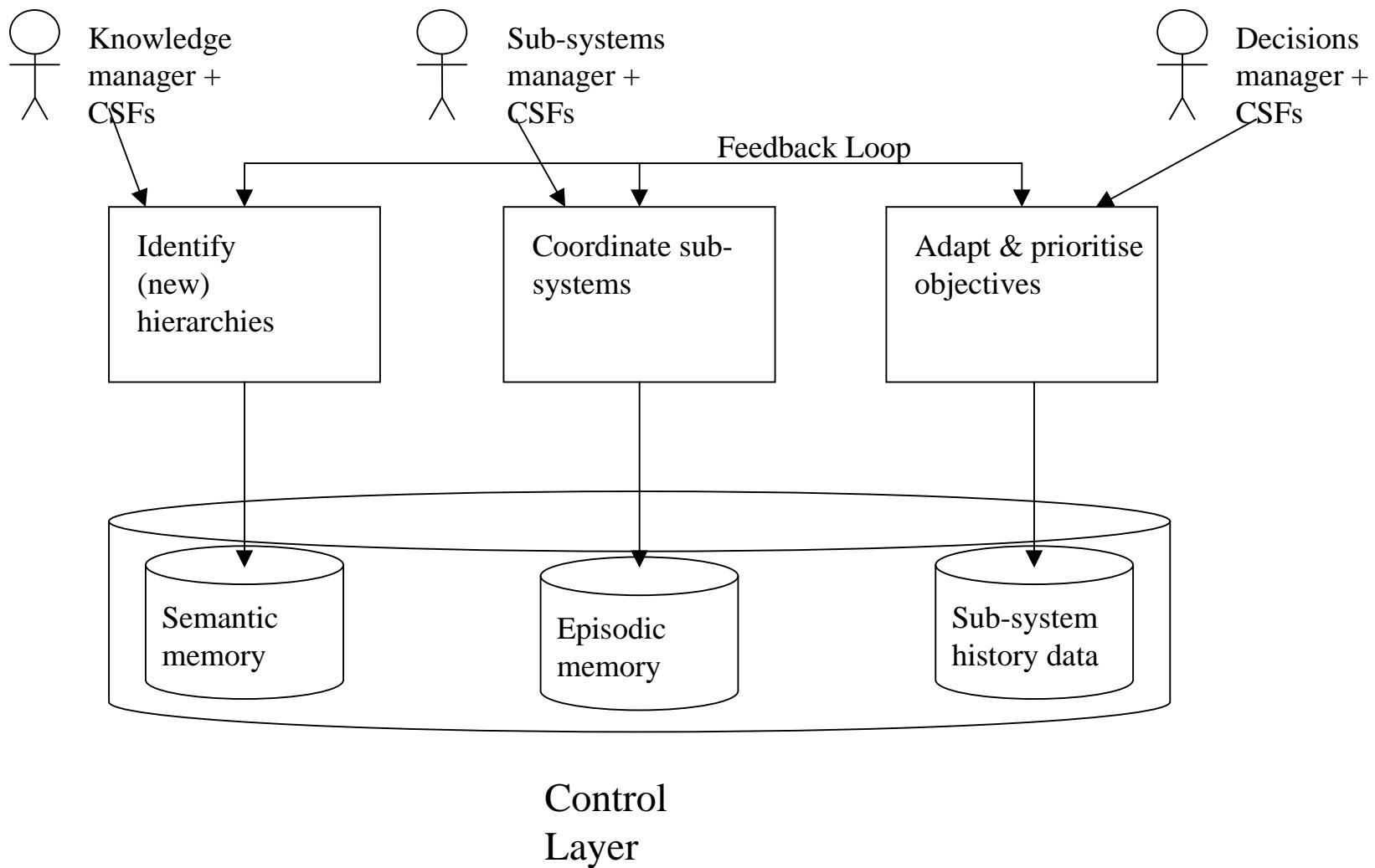
Control Layer

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