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"Assessing the impact of digital communications technology on existing C2 systems; a distributed cognition perspective"

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Assessing the Impact of Digital Communications Technology on Existing C2 Systems; a distributed cognition perspective

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Abstract

In this paper, we evaluate the impact of new communications technology on Command and Control (C2) systems from a distributed cognition perspective. This continues preliminary research presented at the 10th ICCRTS (McMaster, Baber and Houghton[1]). Distributed cognition (DC) is the branch of cognitive science which treats groups of individuals and artefacts engaged in the completion of a common task as a single cognitive entity, revealing features of the activity which other approaches can miss. During 2005, UK Police forces completed the transition to the Airwave digital radio system, which is thought to offer greater interoperability and potentially improved coordination during emergencies. West Midlands Police (WMP) C2 processes were studied using observations of emergency incident responses, incident log data and interviews using the Critical Decision Method to compare DC features of the C2 system before and after the introduction of the Airwave system. Digital communications have not significantly impacted upon systems-level cognitive processes taking place during WMP responses to emergency incidents, however possible changes to the organisation of incident management which are supported by the digital communications network may enable more rapid propagation of information through the system and result in improved coordination of activity across multiple incidents.

1 Introduction

1.1 UK Police Communications

During 2005 all UK Police forces converted from analogue UHF and VHF radio networks to adopt a digital radio system[2]. These new radio networks operate using TETRA (Terrestrial Trunked RAdio) – the European standard for digital telecommunications, which defines the way that voice and data communications are to be handled and ensures interoperability across compliant equipment manufacturers and network providers[3]. Once all UK Police forces (and eventually all UK emergency services) have moved to TETRA compliant radio systems, the ability to coordinate activity both regionally and nationally is expected to improve, with personnel from different forces and services being able to communicate directly, using their own dedicated networks.

The system chosen to provide UK Police forces with TETRA radio is called Airwave and is provided by the mobile telecommunications company O_2. Replacing analogue radios, Officers have been issued with multi purpose handsets that can function as radios, mobile phones and data terminals[2]. A number of benefits of the Airwave system for UK emergency services are anticipated, including improvements to levels of coverage, security of communications and the use of data transmissions to and

from Officers in the field[2]. At the time of writing, all UK Police forces had been using the Airwave system for at least 12 months[2]; given the intensive nature of emergency response activity and the reliance on radio communications, this should have been sufficient time for staff to have become familiar with the operation and capabilities of the new radio system and to have settled into a new routine for handling emergency incidents. This presents an opportunity to investigate the impact that digital radio communications have had on UK Police emergency response C2.

The introduction of new technologies to existing C2 systems is a relevant concern for other domains, including the military - where new operational concepts, such as Network Centric Warfare (or Network Enabled Capability) will require further developments in communications infrastructure and the resolution of interoperability issues. By studying the impact of new technologies on analogous C2 systems, lessons may be learned which could be applied in the development of these future systems.

1.2 Distributed Cognition

The distributed cognition approach takes the view that any system, regardless of size, that is engaged in problem solving can be defined as a cognitive entity[4]. Studies of distributed cognition investigate systems-level cognitive processes occurring in groups of individuals and artefacts (for example technologies or language) that are working towards the achievement of a common goal[5, 6]. Rather than being contained within a single individual, these cognitive processes are distributed across the system[6]; it is the coordination and communication of human agents – mediated by artefacts – that enables the system to achieve its goals[7]. Within such distributed cognitive activity, the artefacts themselves act as representations of task relevant information and the system arrives at its goal-state by performing transformations (i.e. combining, interpreting and restructuring) upon these representations[4, 5, 8]. The artefacts involved in this process can act as resources for action, in that their design, appearance or functionality may prompt agents to perform certain activities without consciously reflecting on them first[9, 10]. As distributed cognitive activity requires the propagation of representations through the system in order to function, researchers have concentrated on investigating the flow of information between agents in the social network and on the role of artefacts in supporting cognitive activity.

The development of processes and technologies that optimise C2 activity requires not only an understanding of the tasks that must be completed, but also an appreciation of wider social, organisational and cultural factors, which affect the activity in question[11]; distributed cognition enables the identification of those aspects of the wider work environment which impact upon systems-level cognitive processes.

1.3 West Midlands Police

Emergency services control centre activity includes screening incoming calls, establishing the nature and urgency of the incident, reviewing resource availability, prioritising the incident, allocating appropriate resources and managing the incident to its resolution[12]. Pressure is placed on the agents within emergency service C2 systems, as there are invariably numerous incidents taking place simultaneously, which compete for limited resources; the time-critical and often uncertain nature of incidents means that the ability to rapidly collect, analyse and distributed accurate information is vital. WMP C2 system is described in detail by McMaster et al.[1], however a brief summary of WMP C2 features relating to emergency incident responses is given below.

The geographic area of the UK covered by WMP is divided into 21 Operational Command Units (OCUs), each of which has its own control centre and uses local Police assets to respond to emergencies, via radio communications. There are also force wide assets, such as Police dog and armed response units, as well as the force helicopter - these resources are coordinated through the Traffic Section, based in the Force Communications Centre (FCC). Incoming Police emergency (999) calls from members of the public are routed to 999 Operators (also located in the FCC), who record the incident details, prioritise them (as 'Immediate', 'Early' or 'Routine' response) and pass them to the relevant control room; all incident information is captured in a log within OASIS (Operational and Support Information System) which can accessed by multiple users within the C2 system during an emergency and which is the principal method of communication between the various control rooms. When a new incident log is transferred from the 999 Operator to the Resource Allocation Dispatcher (RAD) within an OCU control room, the new log appears on their OASIS screen; the RAD then has to review the incident details and the availability of the Officers on that shift before requesting that the appropriate resources attend the new incident.

Before the Airwave digital radio system was implemented, WMP operated an analogue radio network, which involved some users on VHF systems, whilst others used UHF. The radio system also featured limited communications between local OCU units, who were unable to hear each other's transmissions – messages were relayed by the RAD, unless 'talk-through' was requested, functionality which enabled everyone to hear all messages, but which drained radio batteries more rapidly and so was used sparingly. The analogue communications system also had only a very limited number of radio channels, with only one dedicated channel available for each OCU (though a force wide channel was available if required).

With Airwave, radio communications now take place on talk groups (which are not restricted to a particular radio frequency[13]) rather than channels; within a talk group, all Officers are permanently able to receive each other's transmissions and any Officer is able to join any talk group, enabling specialist force assets (such as the helicopter) to communicate directly with local resources. Airwave provides each OCU with the ability to run up to 10 talk groups simultaneously; alternatively, Officers are able to set up 'point to point' communications (i.e. one to one) with any other Officer in the force, or use their radio handset as a mobile phone – making and receiving calls.

1.4 Distributed Cognition processes of WMP C2

Previous investigations[1, 14] into distributed cognition processes within WMP determined that the C2 network observed during incident responses did exhibit distributed cognition properties; cognitive activity was found to be spread across the network and was facilitated by a number of artefacts, with OASIS playing a key role in the capture, storage, transformation and transmission of critical incident information[1]. During emergency incidents, OASIS was also observed to function as a resource for action, in that it prompted certain activities from the agents involved in managing the response[14].

McMaster et al.[1] modified data collected from incident logs to simulate a more distributed C2 network which could be created by giving patrolling Police units access to OASIS and by sharing all communications between responding units. It was

argued that such a distributed network would support more rapid acquisition, analysis and dissemination of information, which is a priority during the early stages of an emergency incident when the speed of response can be a critical factor. It was also argued that the increased communications would allow attending Officers to self-organise their activity, which may improve responses to emergency incidents. Whilst the implementation of Airwave by WMP has not quite led to the creation of a completely distributed network (as responding units currently do not have access to OASIS logs) the ability to communicate directly with other officers and the resolution of interoperability issues mean that the incident response network now appears far less reliant on central coordination than it was with the analogue radio system. This change in communications technology has the potential to affect WMP C2 activity by altering the work environment, information processing and decision-making activities during incident responses. WMP did not alter their existing C2 structure or incident management procedures when Airwave was implemented and there is the concern that the new less centralised communications network may impact on their ability to respond to emergency incidents, for example by affecting lines of communication, reducing feedback to control centres and compromising the role of OASIS as a comprehensive up to date record of emergency incident details.

WMP Officers and staff have now been using Airwave to coordinate their emergency responses for over a year, so any initial disruption to the handling of incidents during the implementation period should now be resolved. In order to evaluate whether the new radio system has had an effect on the coordination of emergency responses by WMP C2, further investigations were carried out to compare current incident management processes with operations under the previous analogue system.

1.5 Aims of this Paper

This paper describes an examination of Police emergency response C2, concentrating on the effect that the introduction of the Airwave digital radio system has had on the nature of communications, the roles of the agents within the system and the use of existing artefacts in order to evaluate how changes to one artefact within a distributed cognitive system can affect the overall tasks being performed by the system.

2 Approach

Access was granted to undertake several interview and observation sessions with Officers and staff at West Midlands Police C2 facilities; these took place whilst the original analogue radio network was in operation and again after the new digital network was introduced. For the purposes of the present work, attention was concentrated on the analysis of emergency response coordination activity in WMP control rooms. Interviews were held with staff from the FCC and Bournville Lane OCU, during which the revised Critical Decision Method (CDM) probes developed by O'Hare et al.[12] were used to investigate the cognitive processes involved in the resourcing of emergency incidents. CDM interviews were also used to attempt to evaluate the impact of Airwave on incident management, by asking control room staff about example emergency incidents they had handled when using the analogue radio system and similar incidents they had experienced since Airwave had been implemented. Control room staff and supervisors were also asked about their impressions of how Airwave had affected the incident management process in terms of the role of the control centre, the use of artefacts, communications with and

between Officers on the ground and their overall goals in responding to the incident. A process-tracing analysis was used to explore information capture, storage, transformation and communication during the various stages of emergency responses and the different agents and artefacts involved. This resulted in a process flow diagram that was then annotated with a graphical notation system, which depicts the distributed cognition features of a system concisely (further details on the development of this notation system can be found in McMaster and Baber[14]).

3 Analysis of WMP Command and Control System

3.1 Introduction

The following sections of this paper go through the various aspects of WMP C2 that were examined in order to identify what effect the introduction of Airwave has had on WMP emergency incident management.

3.2 Control room environment

Figure 1 (overleaf) shows one of the workstations used by Traffic Section Controllers in the FCC; a number of artefacts that are used in the management of incident responses are marked:

OASIS (1)

Digital Radio touch-screen (2)

Police National Computer / map system (3)

Notepad (4)

Airwave handsets [on the desk at the back of the room] (5)

The only alterations to the FCC since the introduction of Airwave are the digital radio touch-screen, which replaces an older software version that was used with the analogue system and the addition of Airwave handsets; their role in the management of emergency incidents will be discussed later.

Figure 2 (overleaf) shows one of the RAD workstations within Bournville Lane OCU control room, again highlighting the artefacts that are used during the management of incident responses:

OASIS (1)

Digital Radio touch-screen (2)

Police National Computer / map system (3)

Notepad (4)

The OCU RAD workstation is the same as it was prior to the implementation of Airwave, except for the updated radio touch-screen software.

Figure 1: FCC Traffic Section workstation

Figure 2: OCU RAD Workstation

3.3 OASIS Record of Incident Response

The OASIS log of an incident represents the official, legally admissible account of WMP activity in responding to an emergency. In order to investigate the effect of the use of Airwave on how emergency incidents are responded to, we compared the OASIS logs of 'immediate response' incidents from pre Airwave operations with logs of incidents that had taken place since Airwave implementation had been completed. Two examples of similar incidents taken from OASIS are summarised below.

'Burglary in progress' (Analogue Radio system)

During the late morning, a member of the public witnesses a young man kick open the back door of a house; another passer-by calls 999 and relays this information to the 999 Operator, who summarises the information in a new incident log and passes it to the OCU for the incident area and the Traffic Section. The OCU RAD accepts the log, despatches resources and requests that the Traffic Section despatch a dog unit to the location. The Traffic Section Operator accepts the log and redeploys a dog unit from another incident. The first responding unit arrives at the scene and is given a description of the offender and the direction he ran off in. The unit passes this description to the RAD who relays it to the other responding units; they then search the surrounding area for the offender. The dog unit arrives at the scene and begins to try and track the offender; other units arrive and interview the witness and caller. The unit searching the area reports to the RAD that they have stopped a man nearby who fits the description; the unit interviewing the witness then drives him past the man that has been stopped to confirm whether it is the man he saw breaking into the house. The witness states that this is not the man he saw and this information is passed to the RAD. The responding units continue the search for the offender but he is not located. The council is called to secure the damaged door and the location is passed to Scene of Crime Officers for forensic examination. All resources leave the scene and the incident is closed.

'Burglary in progress' (Airwave)

A woman sees someone breaking into their neighbour's house, calls 999 and reports it to the 999 Operator; the Operator fills in a new incident log and passes it to the relevant OCU and also the Traffic Section. The OCU RAD accepts the log, despatches resources and requests the presence of a dog unit from the Traffic Section. The Traffic Section have not yet accepted the incident switch, so the RAD attempts to switch the incident log to them again. The Traffic Section Controller accepts the log and requests a dog unit attend the incident. Meanwhile, the caller reports that the offender has run off carrying something, gives their direction of travel and provides a description to the 999 Operator. The RAD reads the description from the OASIS log and passes it to the responding units. The Traffic Section Controller reports that there are no dog units available to attend the incident. The first responding units arrive at the scene and speak to the caller, who says that their neighbours are out. One unit attempts to contact the homeowners and performs a search of the area, taking the caller, to see whether they can find the offender. The responding units are unable to locate the offender and cannot contact the homeowners; repairs to the damaged door are ordered and a message card left for the homeowners.

These two descriptions of WMP responses to 'burglary in progress' calls seem to show that similar responses take place during operations using the Airwave system as were seen on the previous analogue system: the call is taken by the 999 Operator who captures the main incident details in OASIS, before routing the incident log to the OCU and Traffic Section; they then despatch resources to the scene and monitor their progress in resolving the incident. However, this only shows that similar information is being entered into the incident log; which does not necessarily mean that either the organisation of emergency responses with Airwave are the same, or that the right information is being captured in OASIS. It may be that relevant incident information is not being recorded, because the RADs are no longer in the communications loop, for example, if responding Officers are making 'point to point' transmissions. The implication of this is that the incident log as recorded in OASIS may no longer contain all relevant information on an incident.

Looking at the time taken to respond to and resolve incidents, there does not appear to be a significant difference in performance since Airwave was implemented; for example, in the first burglary in progress described above, responding units had arrived at the scene 4 minutes and 9 seconds after the call was answered by the 999 Operator and the incident was closed after 1 hour and 20 minutes. In the second burglary in progress, the first responding unit had arrived at the scene 5 minutes and 5 seconds after the 999 call was taken and the incident had been resolved after 1 hour and 38 minutes – which is a slight increase in both response time and resolution time for the Airwave incident. However, as even similar incident types are so context dependant, for example distance to incident location, traffic density, OCU resource levels at the time, it is difficult to attempt to make performance comparisons between them. A more detailed examination of WMP C2 was therefore necessary in order to establish what effect the introduction of Airwave has had on responses to emergency incidents.

3.4 Impact of Airwave reported by C2 Staff

Interviews were held with Traffic Section Controllers and OCU RADs to identify their perceptions of how the introduction of Airwave had affected activity during responses to emergency incidents. Their responses are grouped into five different aspects of WMP C2 activity: communications, coordination of incidents, workload, situation awareness and effectiveness of emergency responses.

Communications

Interviewees reported that Airwave has improved the clarity of broadcasts; previously Officers would sometimes have to repeat their transmission several times and a broadcast would be cut off completely if another unit began to transmit at the same time. The Traffic Section also commented that they had noticed that reception was better with Airwave and that there did not seem to be any coverage problems any more. An increase in the number of communications between patrolling Officers was reported and RADs confirmed that these communications were task relevant, i.e. discussions of ongoing incidents, rather than non-work 'chat'. The Traffic Section had not noticed any change in the volume of radio traffic due to Airwave, however they generally hear very little about routine incidents on Traffic talk groups as the responses are coordinated by OCU RADs using their own talk groups.

Some negative consequences of the ability for any Officer to join any talk group had reportedly been experienced during vehicle pursuits. As soon as a pursuit begins, it is transferred to the Traffic talk group for that area and is run by the Traffic Section; the overall responsibility for all pursuits of fleeing vehicles lies with the FCC Duty Inspector, who will supervise the Traffic Section's management of the incident. RADs will monitor the pursuit and broadcast relevant information out to local units on the OCU talk group. However, WMP have found that local units have been switching to the Traffic talk group to monitor pursuits directly, resulting in the traffic channels being overloaded, as they were not designed to cope with so many users. WMP subsequently had to issue a directive that non-essential units are not allowed to listen in to Traffic talk groups.

Coordination of Incidents

During operations under the analogue radio system, if several units were despatched to an incident, OCU RADs reported that they would try to get the Officers to coordinate the incident themselves (using talk-through), but that, in addition to prioritising resources for multiple incidents, their role also involved a great deal of management of the incident response. RADs reported that, during incidents, they may direct specific Officers to perform activities which had not yet been picked up, for example: "*Unit A is performing search, Unit B: please talk to the witness.*" RADs also reported that the patrolling Officers relied on them to provide detailed local information using their electronic map of the force region (marked '3' in Figure 2) and to use it to coordinate their response to incidents. The map system is able to zoom in on incident locations (updated automatically from the OASIS log), displaying the layout of buildings and the surrounding area, as well as access points to properties (such as alleyways). During burglaries, RADs reported using the map to inform attending Officers which side of the road the property was on, what other buildings or properties it backed onto and suggest actions to take, for example, if several Officers were attempting to establish a perimeter around a property, the RAD may suggest to the senior Officer that they direct a Constable to a specific location. OCU staff reported that with the Airwave system in use, their role in coordinating incident responses is unchanged, as RADs still organise which Officers are to attend each incident and are still called on to coordinate the response if several Officers are dealing with an incident. The RADs reported that Officers on some shifts have begun to coordinate activity on an incident amongst themselves, but that this happened rarely.

The Traffic Section reported that they instruct specialist units as to which incidents to attend, for example sending a dog unit to a burglary in progress. Exceptions to this are armed response units and the force helicopter, which both have restrictions on when and what type of operations they can respond to, for example, the helicopter is limited by the number of hours it can fly and so will only respond to incidents under certain conditions. Once a dog unit has been resourced to an incident, they will switch their radio to the OCU's talk group and the OCU RAD will coordinate their activity from then on. The Traffic Section update the incident log when they despatch resources to an incident, in order to let the OCU RAD know what additional resources to expect. Traffic Section resourcing activity was the same with the analogue radio system; the responding unit would select the UHF radio channel for the OCU as they entered their area.

In the case of vehicle pursuits, which may move through several OCU areas during the course of the incident, the Traffic Section will coordinate the response, directing resources in order to try to resolve the pursuit as quickly as possible (for example through the use of 'stingers' to deflate the fleeing vehicle's tyres), with the various OCUs monitoring the Traffic talk group and updating local resources (on their OCU talk groups). Pursuits were handled in the same way when WMP were using analogue radio – with the Traffic Section coordinating activity on regional (VHF) channels and the OCUs monitoring and broadcasting updates on local (UHF) channels.

Workload

OCU RADs reported that they thought their workload had increased with the implementation of Airwave, as the increase in communications required an associated increase in monitoring activity; they also stated that they now have to mentally filter the communications, i.e. deciding which broadcasts are either directed at them or require their attention, whereas previously all communications were directed at them, unless talk-through was enabled. RADs reported that they sometimes miss broadcasts and have to ask the calling Officer to repeat the communications, as they were attending to other activities (for example, reviewing incidents in OASIS, checking map or database information or making telephone calls). RADs have to select the incident information that needs to be entered into the incident log from the stream of radio communications. Under analogue radio conditions, RADs would monitor the OCU channel, Traffic Section Channels (including the air-ground channel) and one additional force wide channel - if it was in use. Airwave offers the OCU RADs the ability to monitor all 10 of their own OCU's talk groups at once, as well as the Traffic Section talk groups. RADs reported that in practice, they are only able to monitor at most two talk groups simultaneously and only for short periods of time; they will only monitor one talk group during normal operations, as it is too difficult to keep track of multiple discussions on different talk groups. Whilst some planned activities are coordinated using other talk groups, all immediate response incidents are handled on the main OCU talk group, which is the one that the RADs monitor.

With Airwave, patrolling Officers also receive more direct and indirect communications than they did using the analogue radio network; they now hear responses from other Officers to communications from the OCU and they also receive direct communications from other Officers. The OCU RADs reported that patrolling Officers appeared to be attending to transmissions less, as they sometimes had to broadcast to an Officer several times before they received a reply. This may be because, as with the OCU RADs, Officers are finding it harder to identify the radio communications that are relevant to them, due to the volume of communications they receive.

The Traffic Section thought that their workload had not changed as a result of the introduction of Airwave, as they are performing the same activities, with the exception of occasionally listening to OCU talk groups if they want more information on a particular incident.

Situation Awareness

OCU RADs reported that their awareness of the state of ongoing emergency incidents had improved since Airwave had been implemented, which they put down to picking up more details of the incident and the activities of the responding units whilst monitoring the increased radio traffic between Officers. OCU staff also reported that

patrolling Officers liked the increased radio traffic on the Airwave system, as it meant that they had a better idea of what was going on, both with incidents they were responding to and with other emergencies which they may have to become involved with. The Traffic Section supervisor thought that their awareness of emergency incidents was about the same with digital radio communications.

Effectiveness of Emergency Responses

Both OCU RAD and Traffic Section Controllers reported that they had not noticed any difference in terms of the speed of response or speed of incident resolution as a result of Airwave. OCU staff also noted that any impact of the move to Airwave on incident response performance would be difficult to establish from OCU performance metrics due to a number of other Policing initiatives, which were implemented at around the same time. New Home Office targets for reducing levels of certain categories of crime will have an impact on planned operations and resource levels for different activities, which may affect emergency incident resourcing and response times. Additionally, the new National Standards for Incident Recording (NSIR) are likely to alter the number of incidents raised, as many more Police 'encounters' now have to be logged in OASIS.

3.5 Decision-making during Emergency Incidents

During the interviews with OCU RADs and Traffic Section Controllers, they were asked to recall emergency incidents from before and after Airwave was implemented and the CDM probes were used to gather information about their decision-making at various points during the incident response. The overall goals during the management of emergency incidents were reported as being to protect life, apprehend offenders and protect property, in that order of priority. During burglary in progress incidents OCU RADs and Traffic Section Controllers attempt to get resources to the scene as quickly as possible, as the offender(s) may still be in the area, making an arrest more likely. The decision as to what units to send depends on a number of factors, including the type of incident, location, the other ongoing incidents and the status and locations of patrolling Officers. RADs will also make a risk assessment of the incident and will ensure that the resource level is sufficient for the protection of the Officers involved. The incident details recorded in the OASIS log are the prime source of information for the initial resourcing decisions during an incident. Once Officers are on the way, the RAD will review the log details to decide whether they need to gather further information from the caller to assist the responding Officers to resolve the incident, for example, a description of the offender(s) and direction of travel. The RAD may telephone the caller back to gather this information, provided it is appropriate to do so (during a burglary in progress, calling the owner of the property may alert the offender). Resource levels for an incident may change over time; for instance, resources may be re-allocated if other incidents are reported which take priority. RADs move Officers between incidents in an attempt to provide the appropriate responses using the resources available. In addition, as new information about an incident comes in, this may raise or lower its priority in relation to other open incidents, for example, if it transpires that an offender has already left a burglary by car, then the RAD will not allocate additional resources to the location to contain the area – these resources may then be allocated to other incidents. Both OCU and Traffic Section staff reported that they follow exactly the same decision-making processes for incident management since Airwave has been implemented as they did when using the analogue radio system.

3.6 Role of artefacts in WMP C2

OASIS

OCU RADS and Traffic Section Controllers reported that they did not think that the implementation of Airwave had changed the way they use OASIS, which is supported by their responses to the CDM probes and through the examination of pre and post Airwave incident logs. OASIS is still the main method of communication between the various control rooms and continues to act as a central storage mechanism for incident information. As a resource for action, OASIS continues to cue activity from various agents in the C2 system, for example, the incident summary *"Burglary in progress"* and a priority of *"Immediate Response"* entered in a log by the 999 Operator will prompt the RAD to immediately request that any available units proceed to the location, without them having to stop to consider what priority should be assigned to a burglary in progress – the 999 Operator has already made this decision.

OASIS supports RAD incident management activity in a number of ways; it contains a record of the Officers that are on duty in the OCU and lists them according to their availability status (for example "on a break", "taking suspect into custody"). Over the course of a shift, the Officers on duty and their status will change a number of times; the list in OASIS allows the RAD to select the most appropriate resources for an incident according to their availability, without having to consider whether they are on duty or not (they are not on the list if they are off duty). When the RAD records in an incident log that an Officer is in attendance, OASIS automatically updates the resource list; OASIS will also prompt the RAD every 4 hours to check whether each Officer on the list is still on duty, this helps the RAD to keep the resource list up to date without having to remember when each Officer has come on duty.

Bournville OCU reported that they may deal with over 80 incidents during a busy shift; OASIS supports the management of a large number of ongoing incidents by reminding the RADs every 20 minutes of each incident that is still open, meaning that they do not need to try to remember all of the open incidents at once and prompting them to check on the other incidents if they have become focussed on one emergency in particular. It may be that the RAD has heard nothing from the Officers responding to an incident for over 20 minutes, in which case the reminder cues them to radio the attending Officers for an update, so they do not have to remember to do this themselves. If there is no activity taking place on an incident, then the RAD may defer it until a later time, for example, if a statement is needed from a witness before the log may be closed, but the witness is unavailable until the following day, the log may be deferred until that time and will not come up again until the defer time is reached. In this way, non-emergency incident activity may be scheduled for a later time, leaving the RAD to concentrate on managing the active incidents.

OASIS also assists in the creation of the formal record of activity undertaken by WMP in the response to an incident; in addition to comments entered manually in the log by the various agents involved in the incident response, OASIS will automatically create log entries when certain actions are performed, for example, when the RAD first opens the incident log, OASIS automatically generates the message:

"Incident transfer accepted by terminal [NUMBER]"

This update can then be seen by the 999 Operator who is handling the call, indicating to them that the relevant OCU is now organising the response to the emergency; the entry also becomes part of the record of the incident response, indicating who took ownership of the incident and when (all entries are date and time-stamped). If the RAD re-allocates an Officer to an emergency from another incident, then OASIS automatically makes an entry into the other incident log to reflect this:

"[CALL SIGN] Redeployed to incident [LOG NUMBER]"

This not only assists the RAD in keeping track of which Officers are attending each incident (preventing one Officer from being resourced to two or more incidents at once), but also assists in the creation of an accurate, up to date record of all incidents, not just the one that the RAD is concentrating on at any one time.

Map System

This study has also revealed the important role played by the map system in supporting WMP incident responses; the system converts text-based incident location and priority information from OASIS logs into graphical symbols on a map of the area, listing the attending resources next to each incident symbol. Whilst RADs are heavily reliant on OASIS logs to provide incident information and cue further incident management activity, the map system converts the task of determining the closest resources to a new incident and which incidents should take priority into one of glancing at the screen and noting the position and colour of incident markers, thus reducing the cognitive demand on the already busy OCU staff. The map system is also frequently used to provide location details to units responding to an incident; in this role, the system is more useful than a static map of the area, in that it automatically indicates the location of the incident, saving the RAD from having to look up the address in the OASIS log and convert this into a position on the map. The zoom function on the map system means that, as well as enabling the RAD to provide directions to the location, they can also extract a much greater level of detail than is available from standard road maps. It is therefore unsurprising that responding Officers have come to rely on the use of this system (through the RAD), rather than trying to use maps in their cars or to spend a great deal of time and effort on developing and in-depth knowledge of the local area.

Airwave handsets

During operations with the analogue radio system, patrolling Officers tended to carry mobile phones, but these were not Police issue and so they would often ask the OCU RAD to make calls relating to emergency incidents on their behalf, for example, telephoning the council to arrange for a smashed window to be boarded up. The RADs reported that, since Airwave was introduced, they are still asked by Officers to make calls relating to emergency incidents or to provide telephone numbers of colleagues, despite the fact that the Airwave handsets are able to function as mobile telephones and can be used to store numbers.

Traffic Section Controllers reported that they now use Airwave handsets to monitor OCU talk groups; this is only used for specific vehicle-related incidents that have the potential to develop into pursuits, for example, if a local unit has reported that they are following a car that has been reported stolen. The Traffic section will need to take over the management of the incident if it does develop into a pursuit, so they will listen in and begin to plan possible courses of action should this eventuality occur.

The Traffic Section Controllers reported that this type of incident occurred only infrequently and that OASIS still remained their primary source of incident information. Both Traffic Section and OCU RADs were already able to monitor each other's communications using the analogue radio system and this is still possible using their radio headsets, but Traffic Section staff reported that it is slightly quicker to change the talk group on an airwave handset than to search through the touch-screen menu (marked '2' on Figure 1) to find the appropriate talk group for a specific OCU. The Traffic Section Controllers and OCU RADs reported that they never broadcast on each other's talk groups – all communications between the control rooms still take place through entries made in OASIS incident logs.

3.7 Presenting Distributed Cognition Processes

Observations and analyses of OASIS incident logs were used to produce process flow diagrams of emergency response management; the decision-points identified during the CDM interviews were then used to validate the process flow. For each operation in the flowchart, there is an associated distributed cognition observation regarding how the agents and artefacts involved act upon the information flowing through the process. The features of each operation that relate to the wider cognitive actions taking place in the process can be represented graphically; Figure 3 (overleaf) shows a single operation from the emergency response process that has a summary box attached to it, which uses icons to display the status of various distributed cognition features for that activity. In this operation, the RAD is requesting attendance at a burglary in progress; the relevant information is extracted from the incident log and broadcast verbally to the OCU talk group via the Airwave network. Such a diagrammatic representation of distributed cognition features allows for a rapid evaluation of even complex processes from a distributed cognition perspective – key transformations of information, for example from one modality or storage medium to another can be identified at a glance. Figure 4 (in the Appendix) shows a section of the emergency response flowchart for a burglary in progress, which has been annotated with the graphical notation presented in Figure 3. The graphical notation indicates how incident information is passed between various agents and artefacts and the numerous transformations that it undergoes during the incident response process (for example, location information changes from a text entry in the OASIS log to a graphical icon in the map system and a verbal briefing from the RAD to the OCU talk group). The boxes on the right-hand side of the figure show the incident information that is being recorded in the OASIS log at any particular point, indicating how the record of incident activity is gradually developed. Aside from some minor changes, the graphical notation for the current response process is the same as it was with the analogue radio system; there are some different artefacts involved, but the same cognitive processes are being performed; information processing (i.e. information collection, storage, transmission and transformation) takes place within the same organisational structure, with existing work practices and overall goals and supports the same set of key decisions that are made for an incident, so the overall result is that the C2 system behaves in the same way.

The depiction of the incident response process presented in Figure 4 is from the perspective of control room operations, as that was the focus of the study. It may be the case that more noticeable differences would be found through a study of the response process from the perspective of responding Officers, however the accounts from OCU RADs and Traffic Section Controllers indicate that Officers in the field are

predominantly performing the same activities with similar levels of support from control room staff.

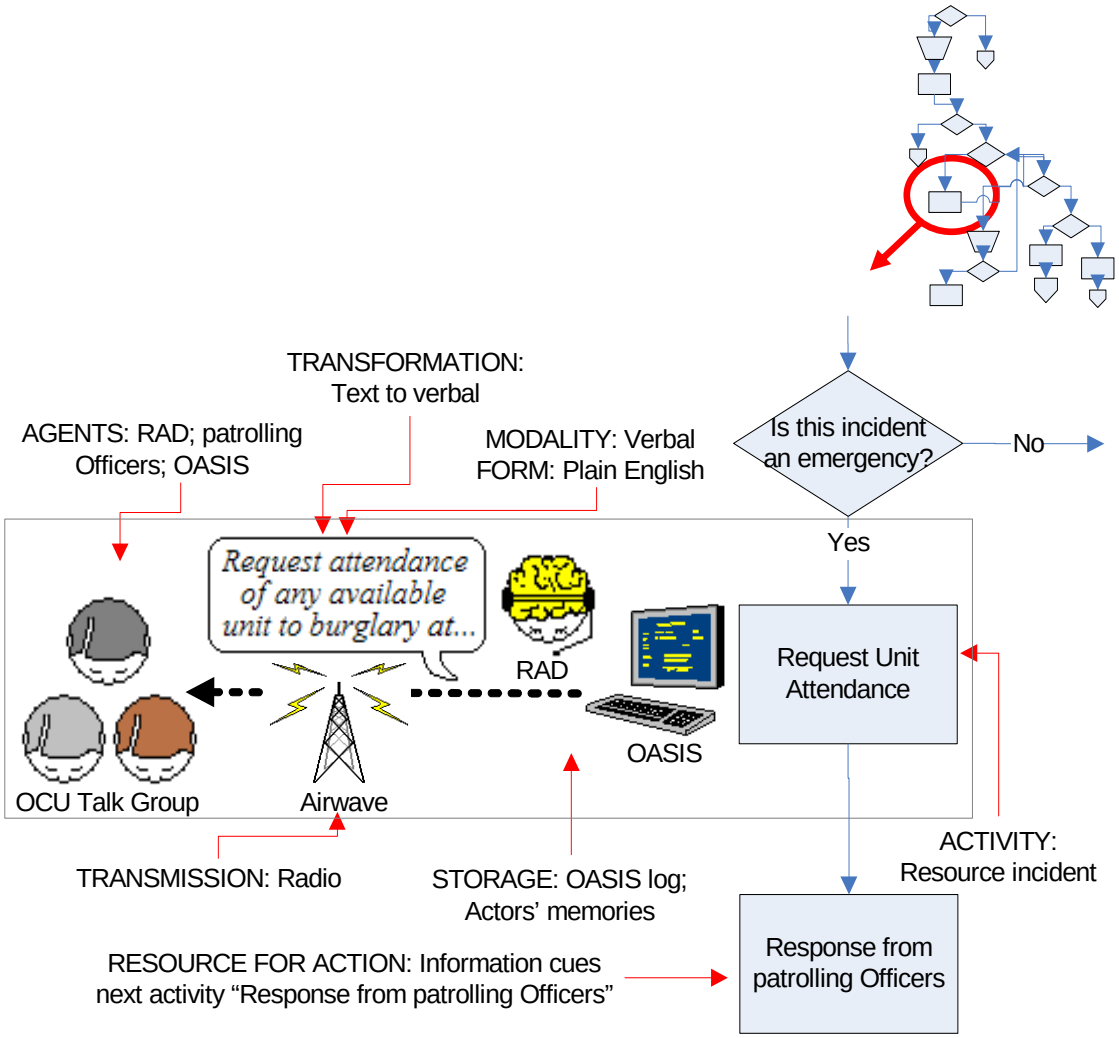

Figure 3: Part of the emergency response process, with the Distributed Cognition notation added (explanations of symbols are included).

3.8 Summary of Findings

The account of WMP emergency response management presented in the previous sections of this paper indicate that, although the introduction of Airwave has brought improvements to the clarity and distribution potential of radio communications, digital radio has not had a significant impact on the performance or practices of WMP C2 in the management of incident responses. Fears that the move to a less centralised communications network would negatively impact on WMP handling of emergency incidents do not appear to have been realised: the C2 system is still performing the same activities in the same way, the role of key artefacts - such as OASIS - in supporting and recording this activity appear to be unchanged and WMP Officers and staff that were interviewed had not noticed any changes to WMP effectiveness in responding to emergencies, despite the reported increase in workload from the increased level of radio communications. Control room staff reported increases in situation awareness since Airwave was implemented, though as this increase does not

appear to have affected the types of activities performed or speed of responses to incidents, it may be that the additional information now available to them is not directly beneficial to the performance of their tasks during incident responses, serving only to reassure them that the incident response is progressing satisfactorily.

Whilst the adoption of Airwave has not negatively impacted upon WMP incident response management, it would also appear that the full capability of the new radio system is not being exploited, in terms of the full use of available talk groups and existing handset functionality; Airwave enables close coordination of responding units in the resolution of emergency incidents, however the existing organisational structure, work processes and use of supporting artefacts support the performance of emergency response activity in the same way as before.

4 Discussion

Whilst the implementation of Airwave has so far left WMP incident response activity predominantly unchanged, future developments of the digital radio system may require work practices to be adapted to better fit the technology, otherwise the performance of the C2 system in handling emergency incidents may be compromised.

The ability to send and receive text to Airwave handsets may soon allow patrolling Officers to have access to incident logs from OASIS, enabling them to review incident details directly and update the log with summaries of activity. This may prove beneficial, in that it could reduce the number of communications from RADs to Officers to brief them on the nature of the incident, as well as reducing the amount of support that RADs have to provide to individual incidents, for example allowing Officers to enter the required write-up to close an incident or enabling them to request force resources from the Traffic Section themselves. However, the resulting loss of RAD control over the incident log may compromise their situation awareness and impact on their ability to manage multiple simultaneous incidents. RADS have already lost control over the OASIS resource list, as many workstations within an OCU can be used to update an Officer on duty's status; if an Officer changes their status in OASIS directly, the RAD will not know until they check the resource list. The RAD may attempt to resource an Officer to attend an incident, having based their decision on what they thought the Officer was doing; their mental model of the status of available resources no longer matches their actual status. The loss of control of OASIS may have a similar effect, in that RADs situation awareness may be compromised; when an Officer radios the OCU with new incident information, this updates the RADs awareness of the state of the incident, if Officers enter information directly into OASIS then the RADs situation awareness may diverge from the actual state of the incident. However, given the large numbers of concurrent incidents occurring at any one time, allowing Officers to access and update incident logs could prove beneficial, provided they take on more of the coordination activity for the incident; this would then enable the RADs to concentrate on resourcing new incidents as they come in.

There are plans to update the map system used in WMP control rooms to include information on the location of officers (from GPS functionality in Airwave radios). This could increase the coordination role of RADs during incidents and might require a re-definition of the RAD role to better acknowledge the supervisory nature of their activity. However, as Police Officers are trained and given the autonomy to make key

decisions about emergencies, increasing the amount of centralised control over them during incident responses may have a detrimental effect on their ability to act on their judgements in a timely manner. Instead, it may be better to use the capabilities of TETRA equipment to support decision-making and coordination activity on the ground, for example by passing Officer location information to patrol sergeants, who would then be able to supervise coordinated responses at the scene.

The area of Birmingham covered by Bournville Lane OCU is divided into 3 sectors, OCU staff mentioned that OCU radio communications may possibly be further sub-divided into smaller talk groups covering these 3 sectors, with a RAD for each. This may help to reduce the workload for both RADs and patrolling Officers, as it would reduce the volume of communications they would receive and also increase the relevance of broadcasts that they did hear. Patrolling Officers may then be better able to coordinate their activity within a smaller area and covering fewer incidents. RADs would also have fewer incidents to manage at once, reducing the risk that they may lose track of any single emergency. However, as incidents may require the coordination of resources from OCU, force wide and even inter-force levels, the further sub-division of OCUs would have to be actively managed, consolidating communications on one working group when required.

These changes could lead to more rapid diffusion of incident information (via supporting artefacts) and closer cooperation of responding Officers, supported by OCU and Traffic Section staff; this may result in quicker incident responses and reduce the time taken to resolve open incidents.

5 Conclusions

The introduction of Airwave has not significantly impacted upon the systems-level cognitive processes taking place during WMP responses to emergency incidents, but changes to the organisation of incident management which are supported by the digital communications network may enable more rapid propagation of information through the system and result in improved coordination of activity across multiple incidents. UK Police forces are in the process of undergoing major reorganisation, with several of the forces (including West Midlands Police) set to merge, creating larger regional organisations[15]. WMP could take the opportunity this reorganisation presents to implement new procedures to enable them to maximise the potential of digital radio communications to better support incident response management.

This analysis of Police C2 may be of use to military and other domains that are engaged in the development and implementation of new communications technologies for complex systems: WMP respond to high tempo and often poorly defined incidents which require input from a number of different groups and resources; effective emergency response management is achieved through clear identification of ownership of incidents, well defined procedures and all agents understanding what everyone else’s roles and responsibilities are during the incident. However, unless appropriate changes are made to such wider aspects of the C2 system when new technologies are implemented, existing work practices are likely to persist and consequently the C2 system may not realise the full benefits of the change, or may even experience degrading system performance where existing processes and new technologies make conflicting demands on the agents within the system.

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Appendix

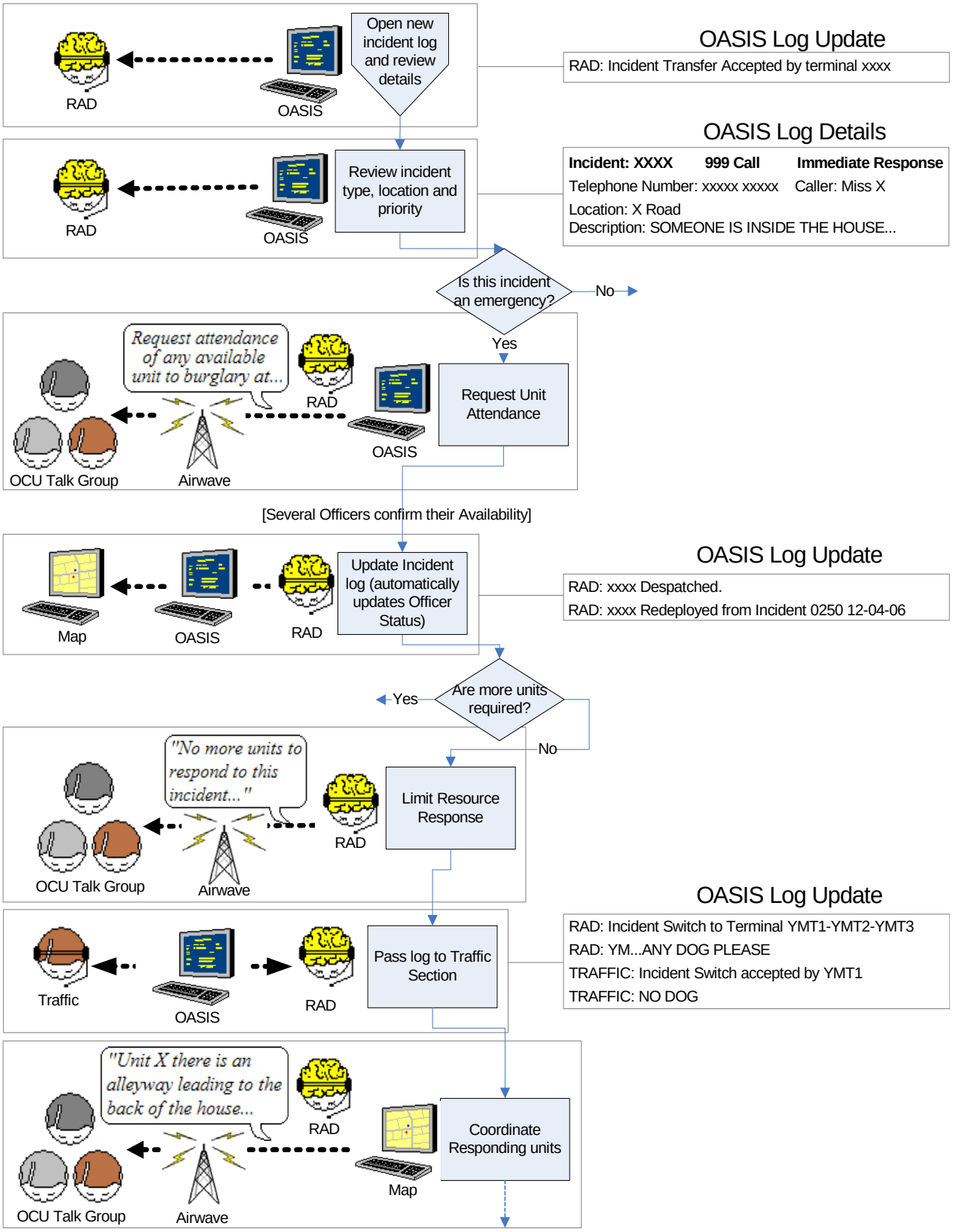

Figure 4: A section of the emergency response process for a burglary in progress, including the distributed cognition notation.