Local and Cellular Communications:

A guide to help policy development

Executive Summary

This note has been developed from an original request to compare "5G vs G5" for Co-operative ITS (C-ITS) for connecting vehicles to other vehicles and road infrastructure in the UK. 5G refers to next-generation mobile communications, while ITS-G5 is local beacon technology. However, our work shows that this is not a simple choice — neither technology is best, on its own, to deliver transport policy benefits. There is also much uncertainty about capacity and coverage, how the benefits could emerge and their size, so there is no clear business case yet to drive a decision, nor a need to decide now between them. The real question is, "What C-ITS applications can deliver network management policy benefit to the UK?" The technologies will follow this answer, not lead it.

5G is the next standard for cellular communications. It offers connectivity not just for road transport but for many Internet of Things (IoT) applications. It is already part of the national investment plan for telecoms. In contrast, ITS-G5 is a specific approach tailored to road user applications. Our work shows that for most applications both 5G and ITS-G5 could technically work but there are key differences in coverage, rollout, adoption and application, as well as who bears deployment cost. These influence the practical choice and will be market-led on a global scale. There is then a question of whether the application is actually used in the real world.

It is likely there will be a global mix not just with emerging 5G but also existing cellular technologies that are already used in many UK vehicles of all ages, not just new vehicles. This mix is reflected in recent technology announcements and EU Strategies. The mix of technologies should be driven by the user and policy-led requirements of the C-ITS applications that government and road users can gain real benefit from. How this mix is managed and glued together is not yet known, although work is underway.

Hence Government does not have to choose a "winner" now — indeed, with such rapid technology and business change this would be unwise. Instead, it needs a framework that can adapt to the emerging global mix of ITS applications and the supporting communications that emerge. It also must continue to invest in pilots and demonstrations to inform the business case for use in UK network management. This transport safety and efficiency perspective needs to be led by government to inform policy decisions. Such pilots and trials will also reduce the uncertainty of the detail of deployment in the UK and inform practical decisions where technology needs to be chosen.

The Transport Technology Forum is keen to work in partnership with DfT, Highways England and CCAV to pull together the public interest perspective of the technology and help Government decide its policy. In this way, UK network management practitioners and industry can be informed and proactive in dealing with technology, and innovative in its global deployment. We can advise on the projects and programmes needed to evidence the business case, and continue to collate and publish informed expert opinion as in this note. We can work with the automotive and communications industries to resolve uncertainties.

So the key is not "5G or G5" but what benefits their use in C-ITS can deliver for the UK, and which of these users will really buy into and actually use on UK roads because of their clear user benefits. Mandating of services will not then be necessary. Understanding these unknowns is the key activity, not choosing a technology.

Introduction

This note records the TTF's thinking in response to the above question raised by DfT and CCAV. It has been developed through the experience of a wide range of contributors including experts from AESIN to ensure a joined-up response between roadside and automotive viewpoints.

The two main options

C-ITS are a complicated and rapidly developing set of technologies. They interact with other transport developments like autonomous/automated vehicles, mobility-as-a-service, and smart cities.

How the elements of any C-ITS applications communicate can be through:

- **Cellular technologies, (often referred to as 3G, 4G, LTE and, when it becomes available, 5G)** based on mobile phone/data services. Cellular's key advantage is that it is already widely used; the networks are continuously improving and sustained by an external business case. Because of this, they can be used in any vehicle, old or new, or indeed by pedestrians, cyclists etc. Existing user devices (smartphones) are easily complemented by systems (apps), and the investment needed on the infrastructure side is made by industry in line with UK communication infrastructure plans, and not as yet by roads operators. Digital Audio Broadcasting and FM radio are also used to send data to vehicles and cellular can be used also for low-cost broadcast.
- **Local (beacon-based) technologies, (often referred to as ITS-G5 [or simply 'G5'], DSRC, 802.11p and others)** transmit data between vehicles and infrastructure using special frequencies and protocols designed purely for transport. Because of the specialist and short-range nature of the link, they are more reliable, more secure, and more rapid than existing cellular communications. However, they require special-purpose products to be installed in vehicles and (for C-ITS between vehicle and infrastructure) at the roadside, and could be more expensive — certainly in the short term.

The TTF and others expect roll-out to involve a balance between the two families of technologies, with the balance depending on the policy problems to be addressed, the timescales for deployment and, as we show, the needs of customers. To emphasise this mix and the rapid change in developments:

- DCMS[1] recently published its plan for 5G rollout which specifically endorses a hybrid "system of systems" approach;
- The EU's[2] recent strategy "presents a hybrid communication approach combining complementary and available communication technologies. Currently, the most promising hybrid communication mix is a combination of WiFi-based short-range communication and existing cellular networks";

[1] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/582383/FCCG_Interim_Report.pdf

[2] http://europa.eu/rapid/press-release_MEMO-16-3933_en.htm

- At the CES show in Las Vegas,[3] automotive electronic makers launched in-vehicle technology able to not just receive and transmit both technologies but also manage their use. The way the mix of ITS-G5 and cellular technologies is managed and glued together is a key area for work; and
- Audi has launched limited signal timing advice services in Nevada using 4G cellular services.

This paper now expands on why we see a hybrid approach as being the best, but we emphasise that this is a snapshot at February 2017. Technology and market developments may change this view.

Where costs lie

Because the core networks are already there, cellular-based services could emerge relatively easily — for example, there is now a wide range of satellite navigation apps using them. Because of the revenue that mobile network operators receive through billing users such as car drivers or vehicle-makers, there is no capital investment but there can be service charges. It does however require wide coverage and there are questions around data ownership.

Local technologies require investment in technology at the roadside and in vehicles. Current examples include access control systems (e.g. where particular "authorised" vehicles can activate a barrier or gate). More evidence of policy-related benefits is required to support a robust business case, for example in wide investment in beacons by a local authority.

The business case — where are the effects?

In many possible uses of C-ITS, there is an asymmetry of costs and benefits, as both cooperating parties need to justify their investment but only one may see a potential benefit big enough to do this, especially as the benefits for many applications are not yet proven in the UK context.

For example, in vehicle-to-vehicle ("V2V") services, the costs are borne by the vehicle buyer/user. When these send information that is useful to others, the benefit to the vehicle buyer is limited.

A similar argument may apply to data sent to vehicle-to-infrastructure ("V2I") services although there is emerging evidence of benefits in fuel savings and reduced delays at junctions. Conversely, while vehicle users might value services received from the road operator (roadworks warnings, etc), the benefit for the city in providing them is not yet proven.

The lower cost of systems using cellular services is an advantage here. However, cellular services still require someone to pay for data and may have implications around data ownership, whereas local communications are owned by the authority. Also, the bandwidth capacity of cellular services means messages may not reach their destinations in busier environments.

This leads to another asymmetry, in that new services using ITS-G5 may be limited to new vehicles, while cellular services could be adopted by older vehicles via smartphones. New

[3] http://gpsworld.com/qualcomm-offers-variant-of-connected-car-platform/

vehicles may have less early penetration than a smartphone-based approach, and may appear to be socially divisive to local citizens — "Why do just owners of new cars get a better deal?"

What can be done with the technology?

The nature of what a C-ITS system affects will dictate the constraints on communications.

For example, driverless vehicles operating in a platoon need communications which are very reliable, very fast, not especially high-bandwidth, and do not need to travel long distances. Local communications are ideal for this and recent C-ITS standards like ETSI ITS-G5 have been developed for this kind of application.

However, information on weather, congestion and other disruptions needs to be broadcast to a wide area, but is not especially urgent and is not safety-critical. Cellular technologies, older wide-area technologies like FM radio, and DAB do this very well already where there is coverage.

There is often a natural desire to use a single communications channel for everything — like using the same internet connection for email and web browsing. The vehicle industry had been encouraging road operators to consider 5G solutions, so that platooning and congestion information (and everything else) could use the same system. However, technology announcements for hybrid approaches in early 2017 suggest this may not be so important — government can choose the applications it wants and the technology choice can follow.

Which technology works with which applications?

The table below lists a set of commonly discussed "Day 1" C-ITS services from the Amsterdam Group, and comments on the applicability of cellular or local communications. It shows few areas where one method or the other is incapable, and in many cases a need for both where both local and wider afield effect is needed.

Note that:

- Some may be a mix of V2V and V2I links, which complicates issues;
- "Cellular" can encompass a wide range of technologies, from 2G through to 5G. We have assumed the most appropriate technology is available (often, but not always 4G or 5G) in line with the "system of systems" view. Broadcast data may use DAB as now;
- The content of what is sent by data comms and the way it is sent are often confused. The contents of the messages (e.g. a Continuous Awareness Message of where a vehicle is) are defined elsewhere. This table focuses on how the message is sent, not the content;
- In some areas we do not know if customer expectation for an "always on" service which is rapidly updated will drive vehicle makers to a particular rapid comms solution, or if customers using other technologies they may not have paid for regard it as "good enough" (or both). The various solutions for sat nav show this, from premium in-vehicle system to free apps;
- Some solutions may only be needed most when communications networks are also busy — e.g. traffic congestion — but some like GLOSA might only work well in off-peak traffic networks when communications loads are also lighter. Work is

underway to examine this peak comms loading capacity as it may be a key factor in technology capability; and

- Some solutions, e.g. emergency vehicle priority, may not in practice be required in the UK due to our operational needs.

Day 1 service	Cellular	Local
Slow or stationary vehicle(s) & Traffic Ahead warning	Timing may be an issue for local warning services but dependent on use case, as road ahead warnings are already done by sat nav using cellular (but immediate road ahead are not)	High level of performance needed for immediate hazard warning
Road works warning	Timing may be an issue for local services but dependent on use case as warnings are already done by Sat Nav using cellular (but immediate road ahead are not). Potential use of data to monitor signal performance	High level of performance for immediate hazard
Weather conditions	Apps available already using cellular but not necessarily immediate road ahead (e.g. icy patch)	Local Comms will provide immediate road ahead warnings (e.g. 'icy patch 100m ahead') but broadcast will be needed for wider messaging ('Snow on Snake Pass – don't leave home')
Emergency electronic brake light	Must be local	Local communications essential for timing
Emergency vehicle approaching	Suitable for vehicles which are further away in the network	Better suited to critical elements such as road crossings
Other hazardous notifications	Suitable for longer-distance warnings, e.g. road works or flooding a mile ahead	Suitable for immediately adjacent hazards (e.g. pothole, debris, animals in road)
In-vehicle signage (fixed signs)	Already done with cellular sat nav for non-time dependent.	Unlikely to be necessary or beneficial for most signs
In-vehicle speed limits	Done by sat nav and OEM device – HE and TfL have shown cellular app – but may be latency issues for smart motorways	May be useful for immediate warnings or enforcement action
Signal violation / Intersection safety	Latency likely to be too high	Needs local comms
Traffic signal priority request by designated vehicles	Most UK bus priority works satisfactorily over cellular using fixed time plans through bus scheduling information	Possible beneficial for emergency services or public transport where the need for dynamic requests are necessary
Green Light Optimal Speed Advisory (GLOSA)	May or may not work well enough for customers and OEM performance needs and depends on if adaptive or fixed time signals. More research is needed on users' needs and performance in peak times	Local comms assure timing of messages

Probe vehicle data	Proven for most applications; signal strategies, journey time, asset management, emissions	Useful as probe data input to signal control algorithms — local data needed for some approaches. But not for wider point-to-point across network information
Shockwave Damping	Driver advice can be provided over cellular (smart motorways)	Local comms needed for automated vehicles, driver support, platooning
Smart parking	Suitable for navigation and payment	Suitable for automated parking (i.e. not under driver control) but not wider zones
Tolling	Suitable for spots, cordons and zones, including payment	Suitable for cordons and zones (non-integrated payment) but not wider distance charging
Infotainment	Well suited, using mainstream entertainment applications	Unlikely to be suitable because of coverage

Red = will not support characteristics this application needs based on current state of art

Orange = supports but dependent on location — i.e. immediate road ahead or general road ahead

Green = should be suitable for many applications

Note that this table reflects technical capability, not cost-effectiveness or effectiveness on outcomes. Also soft factors like public acceptability, ability to evolve, maintainability etc are not included. This highlights the need for more user research as well as technology tests. As an example, GLOSA may work well technically but unless users adopt it as it is reliable and gives them benefit, there is no business case for any technology. The needs of vehicle-makers' customers for timely data may drive a local service, but a cellular service may be good enough for some users.

Gathering evidence

DfT has commissioned TRL to look at the peak loading on communications networks — e.g. for traffic accidents and congestion. The ability to cater for the speed of transfer needed between many vehicles is important. DfT has also funded Middlesex University and Kings College to explore real-world issues of 5G and G5 roadside unit installation and in-vehicle unit radios, including radio propagation and quality. These trials and other evidence emerging from CCAV1 projects will help inform the technical knowledge but more evidence is needed of user buy-in.

Where next?

The key point in C-ITS is not just the technical ability to fulfil a service, but the business case for the outcome that the service achieves and its likely adoption by users. The balance of user penetration, benefits timing and coverage for customers is as important as technical considerations and includes user satisfaction and expectations. Therefore evidence is needed on customer elements such as usability/acceptability, driver response and on the risks and the behaviour of drivers that results and hence affects network management. This knowledge may avoid the need to mandate services.

The emphasis needs to be on outcomes: actual improvements in road safety, congestion, emissions; implications for modal usage and multimodal journeys; freight optimisation etc. Further trials will support the case for either/or both communications methods.

The Transport Technology Forum is keen to therefore pull together the public interest perspective of the technology, in partnership with DfT, Highways England and CCAV, to help Government decide its policy. In this way, UK network management practitioners and industry can be informed and proactive in dealing with technology and innovative in its global deployment. We can advise on the projects and programmes needed to evidence the business case, and continue to collate and publish informed expert opinion as in this note.

We can also work with the automotive and communications industries to resolve uncertainties.

Conclusion

The key is not deciding on “5G or G5” now but assessing what benefits C-ITS applications can deliver for the UK, which of these apps users will really buy into and actually use on UK roads, and the capacity and coverage of the various technologies. Understanding these unknowns is the key activity, not choosing a technology.