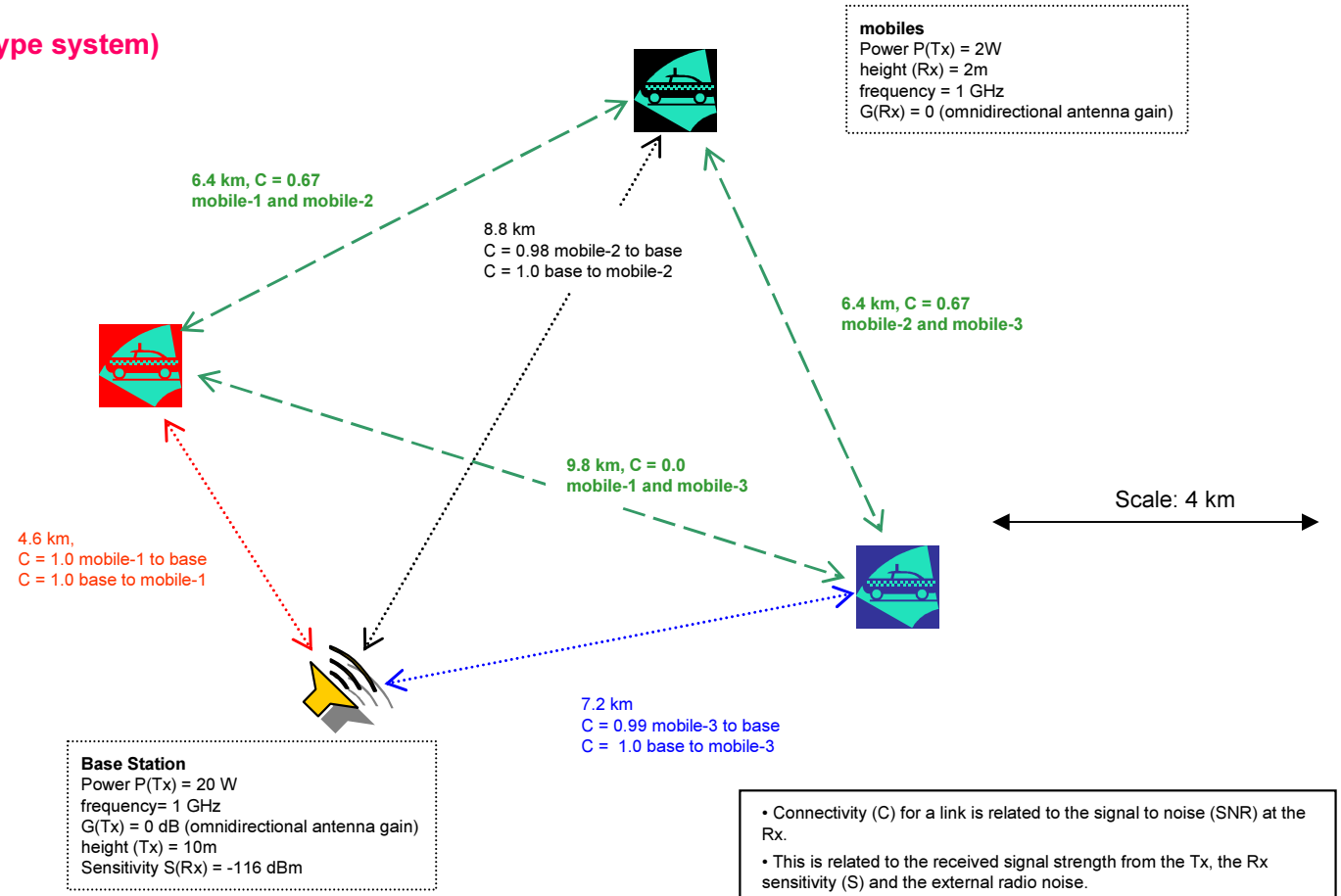
Network connectivity – Base Station and mobiles at UHF frequencies – scenario 3a

Baseline obstruction version (flat terrain <1m undulations, minimal buildings, no significant vegetation – forest/jungle)
All units using basic radios – Base station has better (higher power P(Tx), better sensitivity S(Rx)) than mobiles
Benign radio environment – 'rural' noise level < receiver sensitivity S(Rx)

Examine using an Area Trunk Network ('cellular' type system)

- Scenario 2 examined adding inter-mobile links (green) to the 'centralised – duplex' base station to mobile company links, to give a 'full' net. The rise in connectivity was not large, due to the wide spacing of the mobiles..
- A similar geometry 'full' net is shown here as a baseline to compare an Area Trunk Network to.



Network Connectivity

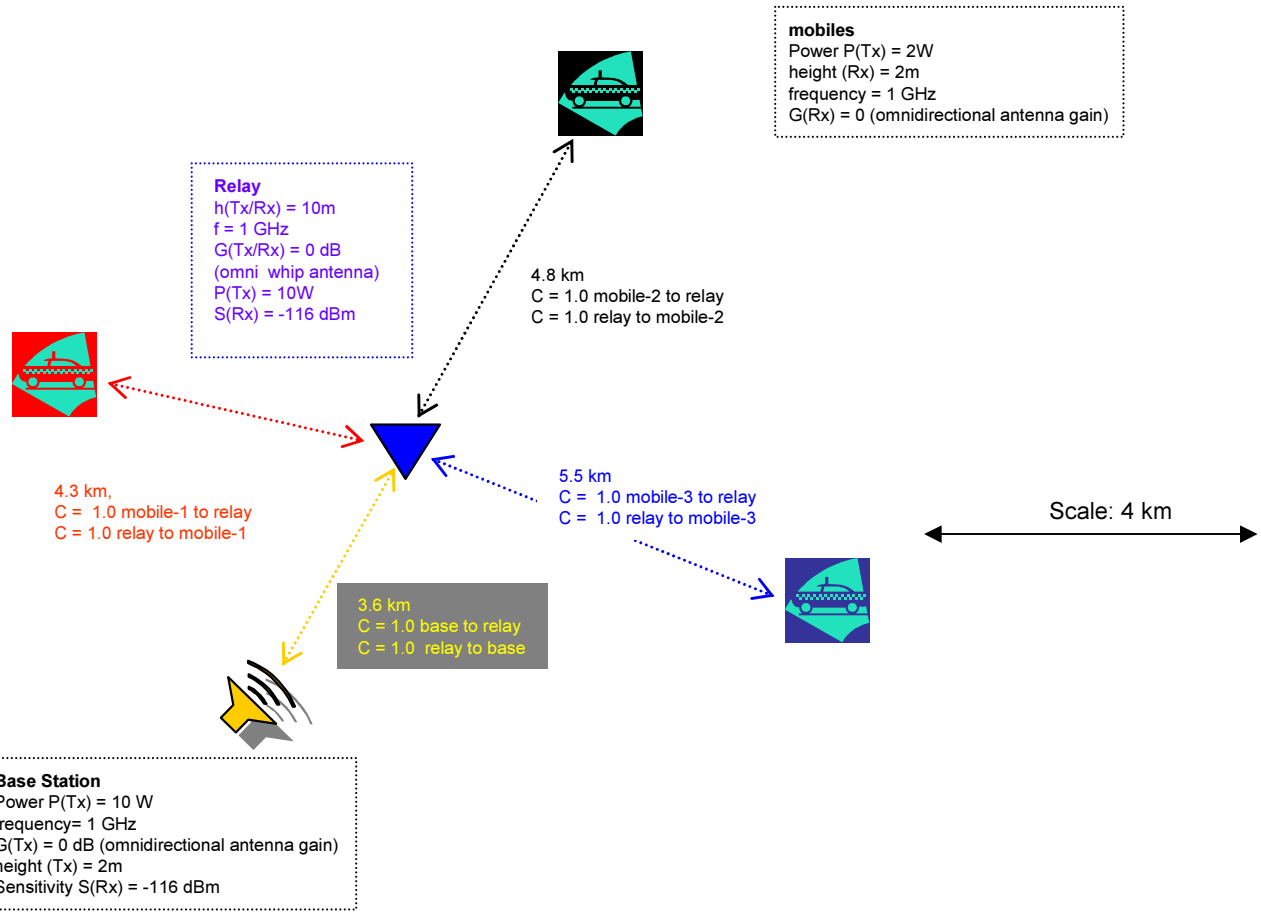
- For the 'centralised - duplex' (between mobiles and base station) sub-net of this network the connectivity is 5.97 across the 6 links (99.5%), nearly perfect for that configuration. However it only has 5.97 out of the potential full 12 links (49.8%).
- For the entire 'full' net the network connectivity is 8.65 across the 12 links (72.1%), a significant improvement over 49.8% even though there is no link between mobiles 1 and 3.
- Across the 'full' net of 12 links, the 'centralised - duplex' sub-net of 6 links makes up 69% of the connectivity (5.97 out of 8.65). The inter-mobile sub-net of 6 links makes up the remaining 31% of the connectivity (2.68 out of 8.65). The inter-mobile sub-net would be more useful it it contributed closer to 50% of the full network connectivity.

- Connectivity (C) for a link is related to the signal to noise (SNR) at the Rx.
- This is related to the received signal strength from the Tx, the Rx sensitivity (S) and the external radio noise.
- For example a 10dB SNR results in C = 0.9, with connection 90% of the time and outage 10% of the time.
- The higher the SNR, the higher the connectivity.

- The full network connectivity (NC) could be improved by having an additional 'Area Trunk Network' of relays (Tx/Rx transponders), similar to a cellular system. These trunk networks are often only used in a static form in permanent networks but it is useful to examine how it could be employed within this mobile network.
- The relays can have 'base station' type radio systems with increased Tx/Rx antenna height on a tower, higher Tx power and more sensitive Rx, but still be relatively mobile as the situation demands. Each unit will make contact with the relay that it has best connectivity with and traffic is passed within the trunk network which has all relays interconnected.
- The base station may be able to revert to a lower Tx power and antenna height as it communicates with mobiles via the trunk network. This could make it more mobile and able to achieve nearly equal connectivity to any unit within the full range of the network area.

Simplest Area Trunk Network - a single relay

- For illustrative purposes the case of a single relay is examined, located near the centre of the network area of operations.
- The Relay has base station type equipment, P(Tx) = 10W, S(Rx) = -116 dBm and an omnidirectional antenna on an 10m tower.
- The base station has reduced Tx power to 10W and reduced antenna height to 2m (e.g. normal vehicle whip) to increase mobility as a tower is not required. As it still has a more sensitive Rx, its links from the relay network are better than the mobile links to the network. Even if the mobile to relay links have C = 1.0 the base station to relay links have greater SNR margin and are thus more robust.
- At the ranges in this example, all the links operate at or near C = 1.0 with 100% availability. It is to be remembered this is a benign environment with very low noise, and no terrain interference.
- The 2-link path via the relay from any unit to another unit has a connectivity equal to the lower of the two links.
- In this configuration there are 8 radio links, compared with 6 for a 'centralised – duplex' configuration and 12 for a 'full' net. However there are 12 paths as every unit can connect with any other unit via a 2-link path.
- The network is completely centralised on the relay so its removal would cause 100% outage, similar to the loss of the base station in the 'centralised – duplex' configuration.



- These 8 links are 100% efficient compared with 72% efficiency of the 12 links in the "full net" configuration. However this configuration is also 100% efficient across all the twelve 2-link paths via the relay, between all units.
- At these ranges there is not much of an connectivity increase on the 'base station to mobile' links, but the network connectivity is significantly increased as the 'mobile to mobile' links are greatly improved. This comes at the expense of overcentralisation compared with the 'full' net but that can be improved with a multiple transponder relay network.
- The potential area of operations of the network is larger as the links tend to be shorter and one end of each link, the relay, has a superior Tx and Rx. The 'centralised – duplex' configuration could only match this by fixing the base station in the centre, losing its mobility. The base station is now free to roam and directly observe or assist in activities the mobiles are performing.

A less centralised Area Trunk Network - multiple relays

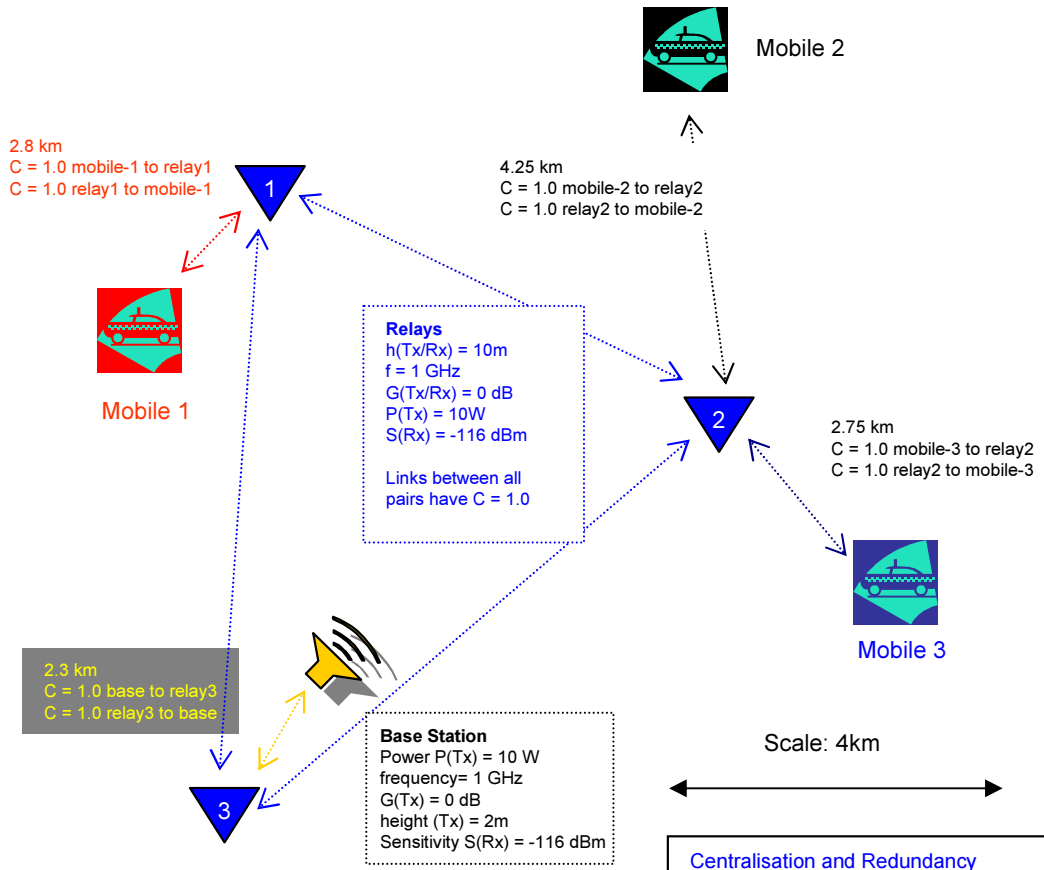
• The three relay network is examined. It is located within the mobile network area of operations, roughly equilateral but slightly elongated to allow for the unit dispositions.

• Relay positioning is constrained by (a) the need to make the connectivity between each pair of relays as high as possible, preferably 1.0 (b) as close as possible to all units (c) providing adequate coverage for the presumed area of operations as units move.

• Hence it is wise not place the relays too close together as they effectively function like a single relay. Similarly they should not be so far apart that, if any were removed, those remaining would be too far from some units to provide adequate coverage.

• For the relay Tx/Rx characteristics shown here, the edge of C = 1.0 range between relays is ~21 km. The configuration here has all the relays separated by considerably less than 21 km and connectivity is 1.0 between all pairs with a considerable margin for decreased SNR due to noise or obstacles.

• As in any cellular system a unit is in contact with the closest relay and the link is established via the relay network to other units.



Paths and Links

• Every unit has a link to a relay in the network and from there a path to any other unit. So there are at least 12 paths in total, at least as many as the 'full' net but much more highly connected. In this case there is full network connectivity.

• Depending on which relay a unit connects to its path to another unit may be 2, 3 or 4 links. The connectivity for each path is the lowest of any link on the path, usually the ones from the units to the relays.

• There are also multiple paths between pairs of units not connected to the same relay. In this 3-relay case a 'short' 3-link path of [unit-relay, relay-relay, relay-unit], e.g. between the mobile-1 and the mobile-3 via relays 1 and 2. There is also a 'long' path using all three relays e.g. via relays 1,3 and 2. Hence if the shorter path is compromised there is redundancy with a higher connectivity on the longer path.

Centralisation and Redundancy

• Using three relays reduces centralisation in the network. Each relay is connected to 4 of the 6 (67%) links within the trunk network compared with 100% for a single relay. It also has more redundancy (2 levels) as the network will still function, albeit at reduced efficiency, with one or two relays removed.

• A two-relay network also has 100% of the inter- relay links connected to each relay but more redundancy (1 level) than the single relay as it reverts to a single relay if one is removed.

• In a four-relay network each relay is connected to 6 out of the 12 links (50%) within the network and there are 3 levels of redundancy.