IEEE P802.11
Wireless LANs

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| --- |
| Use Case Reference List for TGai |
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Abstract

The most current version of this document contains the descriptions of the use cases that will be used to evaluate submissions to TGai.

The clause numbers in Section 3 are meant to be stable over time to allow for continued use case reference by number.

Table of Contents

[1 Introduction 3](#_Toc288013772)

[2 Use Case Descriptions 4](#_Toc288013773)

[2.1 General Methodology 4](#_Toc288013774)

[2.2 Use Case Traits for TGai 4](#_Toc288013775)

[2.2.1 Link-Attempt Rate 4](#_Toc288013776)

[2.2.2 Media Load 4](#_Toc288013780)

[2.2.3 Coverage Interval 5](#_Toc288013783)

[2.2.4 Link Setup Time 5](#_Toc288013787)

[2.3 Values associated with each use case 5](#_Toc288013791)

[3 Use cases 6](#_Toc288013792)

[3.1 Pedestrian 6](#_Toc288013793)

[3.1.1 Electronic Payment 6](#_Toc288013794)

[3.1.2 Traveller Information 6](#_Toc288013795)

[3.1.3 Internet Access 7](#_Toc288013796)

[3.1.4 Mobile Accessible Pedestrian Signal System 7](#_Toc288013797)

[3.2 Vehicle 7](#_Toc288013798)

[3.2.1 Electronic Payment 7](#_Toc288013799)

[3.2.2 Traveller Information 8](#_Toc288013800)

[3.2.3 Internet Access 9](#_Toc288013801)

[3.2.4 Emergency Services 9](#_Toc288013802)

[3.2.5 Inspections 11](#_Toc288013803)

[3.2.6 Resource Management 12](#_Toc288013804)

[3.3 Transit 12](#_Toc288013805)

[3.3.1 Station arrival 12](#_Toc288013806)

[3.3.2 Passenger In-transit access 12](#_Toc288013807)

[3.3.3 Station Lobby 12](#_Toc288013808)

[3.3.4 Connection Protection 13](#_Toc288013809)

[3.3.5 Dynamic Transit Operations 13](#_Toc288013810)

[3.4 Switchover 13](#_Toc288013811)

[4 Prototypical Use Cases 14](#_Toc288013812)

[4.1 Use Case 1 14](#_Toc288013813)

[4.2 Use Case 2 14](#_Toc288013814)

[4.3 Use Case 3 14](#_Toc288013815)

# Introduction

IEEE 802.11 devices are increasingly becoming more mobile devices. TGai project’s primary need comes from an environment where a large number of mobile users are constantly entering and leaving the coverage area of an extended service set (ESS). Every time the mobile device enters an ESS, the mobile device has to do an initial set-up with an access point (AP) to establish wireless local area network (LAN) connectivity. This works well when the number of new stations (STAs) in a given time period is small. It requires efficient mechanisms that scales well when a high number of users simultaneously enter an ESS. This requires the ESS to minimize the time the STAs spend in initial link setup, while maintaining secure authentication.

The goal of this document is to assist in the process of turning use cases submitted to TGai into prototypical use cases. These prototypical use cases will then in turn be used to yield set of requirements that will be used to judge the utility of proposed text for 802.11ai.

Section 3 of this document is a summary all use cases presented to and accepted by TGai. The intent is to gather all use cases and group them into categories of similar traits. These combined use cases are the source for the prototypical use cases listed in Section 3.

Section 4 establishes a small set reference use cases for the purpose of evaluating proposals to TGai. It combines use cases which have the very similar requirements and is an abstracted use case rather than a specific scenario.

#  Use Case Descriptions

The purpose of this document is to gather all use cases that will be considered in the evaluation of proposed updates to IEEE 802.11 that would decrease the link setup time. TGai may determine that some of the use cases contained in this document are required to be satisfied, while others may be desired but optional. In any case, no requirements for technical solutions are required to address issues other than those stated or implied by the use cases in the most current version of this document.

## General Methodology

The basic use case methodology to be used by TGai is explained in 11-11-0191-00-01ai-Use-Case-Discussion.pptx. General use case methodology has four basic elements:

* Actor(s)
* Device sets
* Goal
* Scenario(s)

For TGai, the use cases are somewhat simplified because of the limited scope of the PAR.

## Use Case Traits for TGai

Actors generally define unique characteristics of operators of the devices involved. For all cases considered by TGai, the initiator STA and the target ESS are constant. The STA may be autonomous or operated by a human, but its relationship to the ESS remains the same. If more than one device/person is present in the ESS, that difference should be noted in the description of the scenario. Other important factors, such as relationship between STA and the ESS in terms of assumed level of trust and previous history are also best described in the scenario.

Device sets are the STA, AP, and any other relevant equipment needed to accomplish the intended tasks within the ESS. For TGai, the device set of interest is always a STA and an AP.

Each of the use cases also have (or will have) the determination of the level of difficulty to achieve with the now-current 802.11 technology. The traits which differentiate the use cases are summarized in a table at the end of each use case description. The traits, defined below, are “Link-Attempt Rate”, “Media Load”, “Coverage Interval”, and “Link Setup Time”. An expected value or each of these traits is listed as well as a general indication of difficulty in terms of high, medium, low.

* High = very difficult to achieve
* Medium = difficult
* Low = nominal behaviour, expected to be achieved with current technology

### Link-Attempt Rate

Link-Attempt Rate is the number of STAs attempting to establish a link for the first time to an AP within an ESS as measured over a one second time interval.

* High: more than 50
* Medium: 10 to 49
* Low: less than 10

### Media Load

Media Load is the “busyness” of the wireless medium of the ESS. It is measured as the percentage of time the medium is in use.

* High: More than 50%
* Medium: 10 to 50%
* Low: Less than 10%

### Coverage Interval

Coverage Interval is the time the STA is within the range of an AP within an ESS. This time is the maximum available time for establishing a link and exchanging data.

* High: less than 1 second
* Medium: between 1 and 10 seconds
* Low: more than 10 seconds

### Link Setup Time

Link Setup Time is the amount time required to establish for the first time a link to an AP within an ESS. This includes the time for AP/Network discovery and (secure) Association and Authentication

* High: less than 100 ms
* Medium: between 100 ms and 2 seconds
* Low: more than 2 seconds

NOTE: “link”, “association”, “authentication” are as defined per 802.11

## Values associated with each use case

For each of the use cases that have the same characteristics, the following table will be filled in. “Expected Value” is the quantity assumed to be required to properly describe the use case in question.

|  |  |  |
| --- | --- | --- |
| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

# Use cases

For the purposes of organization, the use cases below are gathered together in terms of the mobility of the STA. The AP is assumed to be fixed, unless otherwise stated.

## Pedestrian

### Electronic Payment

For pedestrian use, the STA (the payee) will typically be located in a kiosk or at a retail store counter and the AP will be part of the retail infrastructure. After bringing purchases to the checkout counter, or at the pickup window of a drive-through store, the customer elects to pay electronically using their Wi-Fi capable smart phone or hand-held computer. The time-critical aspect of the transaction is that the mobile STA may not be within range of the fixed AP until moments (only a second or more) before the transaction is to be completed. In high traffic scenarios, conventional delays in establishing a link can cause unacceptable delays with long lines forming at the counter.

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| --- | --- | --- |
| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

### Traveller Information

A pedestrian is walking down the street, opting to see tourist information about current location. The user has the ability to get map, navigation directions, local attractions, restaurants, etc. Unlike things like the iPhone app “AroundMe”, the information provided would be even more site specific and could be interactive.

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| --- | --- | --- |
| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

Museum attendee –The person obtains information about an object on display as they walk up to the object. Instead of the current recorded voice guides currently in use, this service would be automatically activated by the current location, within a meter or two if necessary, of the user and could even take into account the direction the person is looking in. The information could be multimedia and be interactive.

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| --- | --- | --- |
| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

Knowledge of real-time weather conditions (rain, ice, snow, temperature) along an anticipated route can help a traveler (a potential motorist, transit user, pedestrian or bicyclist) determine whether to reschedule or postpone the trip, or take an alternate route or mode. This application includes continuously collecting weather-related probe data generated by probe vehicles, analyze, and integrate those observations with weather data from traditional weather information sources, and develop highly localized weather and pavement conditions for specific roadways, pathways, and bikeways. The role of 802.11ai is to provide a means of disbursing the current and forecasted information via the Internet and personal communication devices at high density user locations where devices will have relatively short dwell times such as rail/transit stations.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

### Internet Access

Mobile devices perform Internet access while walking. There is the possibility of the person running, not just walking, such as when a jogger is asking for streaming music.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

### Mobile Accessible Pedestrian Signal System

This application integrates information from sensors commonly available on a smart phone, and then wirelessly communicates with the traffic signal controllers to obtain real-time Signal Phasing and Timing (SPaT) information, which will then be used to inform visually impaired pedestrian as to when to cross and how to remain aligned with the crosswalk. The application will allow an “automated pedestrian call” to be sent to the traffic controller from the smart phone of registered blind users after confirming the direction and orientation of the roadway that the pedestrian is intending to cross. The traffic controller can hold or extend the walk signal until the visually impaired pedestrian has cleared the crosswalk. In addition, the application would also enable communications between vehicles and the pedestrian (V2P) at intersection crosswalks. Drivers attempting to make a turn will be alerted of the presence of a visually-impaired pedestrian waiting at the crosswalk. The application can also warn the pedestrian not to cross when an approaching vehicle is not likely to stop at the crosswalk while the light is transitioning to red for automobiles. The V2P concept can also be applied to alert drivers of the presence of non-visually impaired pedestrians and bicyclists, and vice versa, increasing safety of the non-motorized traveler. IEEE 802.11ai APs may be a cost effective alternative for intersections not equipped with public sector IEEE 802.11p RSEs.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

## Vehicle

### Electronic Payment

Fuel payment – This is like the conventional gas station pump credit card payment except that the charge is being made electronically via a Wi-Fi connection. The only need for low latency in this scenario is the potential delays that would be objectionable to the driver before pumping can begin.

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| --- | --- | --- |
| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

Rental car processing – As a rental car drives through the gate upon returning, all relevant data is automatically transmitted to the office and the car “checked in”. The car’s diagnostic connector supplies key information such as the vehicle ID, mileage, fuel level, and any diagnostic codes that appeared. All electronic fees paid for by the on-board systems, such as tolls, parking, fuel, or retail sales, that were charged are added to the rental bill. This not only improves the check-in procedure, but also allows rental cars to use electronic toll collection and parking, which they cannot easily do today.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

Fuel payment – This is like the conventional gas station pump credit card payment except that the charge is being made electronically via a Wi-Fi connection. The only need for low latency in this scenario is the potential delays that would be objectionable to the driver before pumping can begin.

|  |  |  |
| --- | --- | --- |
| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

### Traveller Information

Special maps and directions being downloaded as needed. Such downloads could occur spread out over multiple APs to distribute the download time. For commercial trucks, this could include downloading special routing and delivery instructions from their dispatcher and automatically updating the dispatcher with their status and location.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

Car driver – The driver (or passenger) obtains information about upcoming road conditions and travel times from a roadside AP. Could be expanded into automatically diverting traffic to alternative routes and providing turn-by-turn directions while on these detours. Each vehicle would be assigned to a specific route and thus may be getting unique directions.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

Curbside Parking Availability System -- Travelers desire to know of available parking spaces in real time via the Internet as well as via navigation devices (handheld devices, in-vehicle systems). Parking information will include the location, rate, type, and hours. The information on available spaces will be sent from the fixed sensors or the vehicles to a central server for processing. Travelers access the real time parking information via an IEEE 802ai AP wherever coverage is available either prior to or during a trip and can receive updates en-route. APs can be strategically placed in the vicinity of the parking areas to assists motorists finding spaces.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

Multi-modal Real-Time Traveler Information -- This multi-modal application uses real-time data and communications capabilities to empower travelers to make informed travel choices in real time, pre-trip and en-route. Based on real-time and historical travel conditions for the traveler’s trip (pre-specified origin, destination, and time of departure) the application will suggest potential routes and modes (e.g., auto, transit, bicycle, walk) with approximate travel times, travel time reliability, and costs for each alternative. If transit is included in one of the alternatives, locations of transit stations, arrival time of next bus or train, parking availability and cost, will be also be provided. The application will “predict” travel times based on existing and predicted traffic congestion, weather and pavement conditions, incident locations, work zone locations and timings, transit availability and schedule, parking availability, possible use of HOT and HOV lanes (depending on time of travel). Information may be provided via: personal mobile devices, transit stations on vehicle interactive screens, in-vehicle devices, internet, and 511. TGai APs can be used for Internet connections and communications with both in-vehicle and personal mobile devices.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

Dynamic Speed Harmonization -- This application will be used to monitor real-time traffic and weather data to check if lane-specific speeds within a pre-specified zone indicate the onset of congestion or an increased risk of freeway breakdown conditions. If congestion precursors such as unstable flow patterns, are either detected (in the near-term) or predicted (in the longer-term), the application will calculate and communicate lane-specific target speeds within as well as upstream of the impending bottleneck to motorists via dynamic signs placed on overhead gantries, RSEs to vehicles with range; and from vehicle to vehicle. When RSEs are not available, IEEE 802.11ai APs may be a viable alternative.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

### Internet Access

A person in a car requesting Internet access at any time under any driving circumstances in which there is available coverage. This may be within a parking garage to obtain information about stores in the area or it could be along the roadside for Web access or to download files or streaming audio/video.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

### Emergency Services

Traffic Signal preemption – Currently, many emergency vehicles are capable of causing a red traffic light to turn green via strobe light communication with the traffic signal controller. Using 11ai, this capability can be greatly expanded, not only in terms of the operating range, but also to take into account the navigation plan of the vehicle so that other lights in the area can be controlled to clear traffic in advance of the emergency vehicle’s arrival at the intersection, but to account for planned turns. This can include video of the scene they are going to and updated navigation directions to account for previously unknown problems.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

An extension of this application is the ability for the emergency vehicle to directly communicate with private sector vehicles ahead of it (and those approaching on cross streets) that they are approaching, from which direction they are approaching, and especially important in congested urban areas, if they desire the private vehicle to move to the right or the left depending on the needs for clearing the intended path.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

Ambulance interaction with hospital – an ambulance can upload vital patient information to the hospital they are going to (or to any other specialists that need to be consulted) while en-route. Such data may include video as well as instrument readings. If the AP is available, such data can be uploaded prior to leaving the scene, perhaps as a means of better defining the best course of action.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

On-site emergency services coordination – Establish a temporary IP network on-site to go beyond what can be done with simple voice-based systems. In addition to voice, text, and graphics (e.g. building plans), video from a variety of sources can be shared by all on-site responders and shared with fixed site control centers.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

Public Interaction – During an emergency situation, there is a need for improved communication between the emergency services agencies and the public, whether this is to on notice about a situation, to assist in looking for someone (e.g Amber alert) or to conduct an evacuation of an area. The public can be advised about actions that they should take that is specific to their location (don’t send out a city-wide evacuation when only a small specific area is involved) and manage the routing of cars and people to avoid grid-lock for either an evacuation or simply when temporarily rerouting traffic.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

Incident Scene Pre-Arrival Staging Guidance for Emergency Responders

Staging/positioning of public safety vehicles arriving at an incident is typically handled ad hoc. However, task force and mutual aid response may involve pre-planned procedures and pre-deployment of assets. Pre-arrival situational awareness is critical to public safety responder vehicle routing, staging and secondary dispatch decision-making. Still or video images of an incident scene, surrounding terrain, and traffic conditions would be valuable input to responder and dispatcher decisions and actions. Incident status information relayed to both en route vehicles and vehicles at the incident command area could help in establishing safer, possibly less traffic-impeding incident response. Traffic camera images would be routed to moving vehicles via roadside infrastructure (still images or video depending on capabilities). Public safety dispatcher(s)/incident commander would make pre-arrival staging decision based on available data (initial responder reports; vehicle sensors; imagery). Staging plans (possibly graphic/map based) would be transmitted to emergency vehicles en route and upon arrival. Portable IEEE 802.11ai APs can be deployed at the incident management command location to disseminate the appropriate information to arriving vehicles and to responders with portable devices. APs deployed en-route may also provide the information prior to arrival.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

### Inspections

Vehicle safety – There are requirements for operators to not simply keep their vehicles in a safe condition, but to keep records and undergo occasional safety inspection. Using the capabilities of 11ai, the on-board records can be downloaded to a certified inspection station without the vehicle having to stop and physically hand over these records (electronic screening). This would expand on the currently implemented weight-in-motion systems, with the weigh-in-motion function being included in the same system.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

Hazardous Goods (HazMat) – This would enable the automated monitoring and tracking of shipments of hazardous goods (also known as Hazardous Materials or HazMat). Such shipments have prior approval, not only of the goods themselves, but the route to be taken, with considerable paperwork for the various aspects of the shipment. With the capabilities of 11ai and the existence of various roadside APs, the shipment can be tracked in real time, including monitoring the status of the goods and any on-board security systems.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

Border Crossing – All of the necessary paperwork, including driver information (which can include biometrics) can be transferred to the boarder inspection station as the vehicle is approaching the station. Many border crossings have periods of congestion that result in long backups which not only cause a waste in time, but also can cause traffic management problems.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

### Resource Management

Vehicle tracking – All fleets attempt to keep track of all of their vehicles at all times. Widespread Wi-Fi hot spots along roadways and throughout urban areas can be used by trucking fleets to quickly link to their home office to not only indicate where they are located, but at the same time to download any necessary updates to the driver.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

Dynamic Load Allocations and Routing and fleet management – Currently, especially with Less Than Truckload (LTL) fleets, there is a need to provide dynamic rerouting of a truck to pick up a previously unscheduled load. This is currently done via cellular phones and satellite systems, but would be much more efficient using Wi-Fi. In doing so, with the additional bandwidth available, navigation updates can be made towards the new destination which take into account all other stops that will be required during that day (a capability that is beyond conventional navigation systems).

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

## Transit

### Station arrival

A train with no Wi-Fi access arrives at a station and the passengers want to connect to the AP. A small number (less than 25%) of the passengers will remain in the AP range when the train leaves, 90 seconds after arrival.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

### Passenger In-transit access

The train is a mobile AP which the passengers connect to whilst travelling. The turnover of STAs accessing the AP will be about 25% every 3 to 5 minutes. Users will not log off when leaving the train.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

### Station Lobby

STAs will arrive in a fairly constant rate and want instant access to schedules, status, and optimal transit routes. The transactions may include ticket purchase.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

### Connection Protection

Many public transportation trips require multiple transfers which may be between different modes, such as buses, subways, and commuter rails, and are often across multiple agencies. Travelers desire a connection protection request and receive a confirmation based on a set of criteria, indicating whether the request is accepted. For public transit riders experiencing delays, a high volume of requests may be attempted at a single AP necessitating quick authentication and association. Travelers attempting to submit a request may be en-route (moving).

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

### Dynamic Transit Operations

The traveler uses GPS and mapping capabilities of mobile devices to input a desired destination and time of departure along with their current location. This information will be sent to a central system that dynamically schedules and dispatches or modifies the route of an in-service vehicle by matching compatible trips together. Travelers at rail, subway, or bus transfer stations and depots may present a large volume of requests in a short period of time to a limited number of APs. Travelers may also alter plans or plan a return trip while en-route.

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

## Self growing networking

Non-stationary networks tend to accrete STAs

### Social Networking

Nokia presentation: switch over via TGu. Social networking 0122.

In an interactive session (for instance, skype video) does not always survive when switching from 3G to WLAN

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

If an interactive session switches from WLAN to WLAN, this mode N/A (wifi chipset does not connect to 2 networks simultaneously)

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| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

### Energy-aware end-to-end delay optimization.

Sensor nodes are deployed in a given environment partially covered by a second type of network, e.g. IEEE 802.11 WLAN. The sensor nodes are equipped with a reconfigurable radio unit; they share the communication band (e.g. 2.4 GHz band) with the WLAN but use a sensor network specific MAC protocol optimized for low energy consumption in order to achieve a long lifetime of the sensor network.

During their lifetime of the sensor network, a change in its purpose occurs: in addition to existing functionality, sensor nodes have to report on delay sensitive data to a data sink. For such, the sensor network has to be reconfigured: the routing of messages through the sensor node (multi-hop communication) and the sleep cycle of the sensor nodes has to be adjusted to meet the delay constraints. As a result, the purpose change is achieved but the network’s lifetime is degraded. A cognitive decision entity within the network uses this information to evaluate if a potential synergy of the partially deployed WLAN network with the sensor network can enable the new purpose at better energy cost. Integrating both networks enables additional routes from the sensor to the data sink. Those routes may have different properties in terms of delay. In order to use those now routes to forward delay-sensitve information via the WLAN, sensor nodes have to reconfigure their radio interface to using the 802.11 MAC, find available 802.11 APs, quickly associate to one AP for data offloading, and return to operation using the sensor network specific MAC to act as a relay for those sensor nodes not within coverage of an AP.

|  |  |  |
| --- | --- | --- |
| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate | Less than 50 nodes | Low to medium |
| Media Load | Less than 10 % | Low |
| Coverage Interval | n/a | nodes reside within the BSS’s coverage |
| Link Setup Time | Less than 100 ms | high |

### Purpose-driven network reconfiguration during an emergency situation.

Sensor nodes forming an ad-hoc network are deployed in a given environment partially covered by a second type of network providing centralized, single-hop backbone access, e.g. IEEE 802.11 WLAN.

Both networks had gone through the self-growing phase having resulted in an integrated, symbiotic network under the control of cognitive decision entities: Selected sensor nodes act as gateways of the sensor network to the WLAN in order to reduce the number of hops a message has to travel within the sensor network.

Under normal operation, the sensor network provides sensing information (e.g. temperature in various locations of a building) at low duty cycles; the network is optimized for long network lifetime accepting higher delays in the acquisition of sensing information.

An incident situation occurs (e.g. a fire in parts of a building). As a result, the existing sensor node infrastructure is partially disrupted. Also, as a result of the incident situation, the metric driving the network configuration changes long lifetime of the network is less important. Instead, each sensor node tries to establish the shortest possible link to the Internet and tries to offload its sensing information as quickly as possible (as its destruction might be imminent). It therefore reconfigures its radio, and searches for available WLAN BSSs in order to establish a link as quickly as possible with appropriate APs.

Additionally, the cognitive decision engine controlling the network reconfiguration and self-growing process of the sensor and WLAN network might detect that sensor nodes are located in an are where WLAN coverage is (no longer) given. As a result, sensor nodes are reconfigured to permanently use the 802.11 MAC in order to act as a meshed network re-establishing 802.11-based coverage. Mobile devices of users within the incident area have to quickly discover those newly available “mesh APs” and to quickly establish a link with them.

|  |  |  |
| --- | --- | --- |
| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate | more than 50 | High |
| Media Load | more than 10% | Medium to hign |
| Coverage Interval | more than 1 second | Low to medium |
| Link Setup Time | less than 100ms | high |

### Cognitive Coexistence and self-growing for white space operation

This use cases focuses on a locally deployed access point operating in white spaces in order to form a WLAN providing access to a small (company) network. During its lifetime, the capabilities of the device dynamically grow from an operation without coexistence to a fully coexisting operation mode with other white space devices deployed in the surrounding. In a second phase, the self-growing of the network, the purpose of the deployed network elements grows from only supporting nomadic mobility to additionally supporting seamless mobility for mobile users.

In particular, this is achieved in various ways: A cognitive decision engine achieves separation in (used) spectrum by intelligently assigning valid spectrum portfolios to devices. Hereby, the engine learns about the requirements of each device and intelligently considers a dynamic adaptation of assigned spectrum per node/network. This allows each network to adapt its purpose according to users’ needs (e.g. adding low latency low bandwidth communication for surveillance purposes to existing high bandwidth but long delay services). At the same time, the cognitive engine learns about devices having coexistence issues (and hence are candidates for being in communication range of each other). Hence, the rules of the decision engine at each device are updated to allow a technology specific detection of other (heterogeneous) devices in communication range. Where applicable, the cognitive decision engines may decide to trigger a reconfiguration of devices enabling direct communication among existing networks. This self-growing phase enables additional services. First, direct (or multi-hop) wireless links among deployed devices allow to distribute among several low-bandwidth wired connections (e.g. DSL lines) the traffic going to and coming-in from the Internet. This enables high-throughput communication and allows fully exploiting the capacity of the wireless communication medium. Second, existing homogeneous network elements originally not in the communication range of each other and support nomadic mobility of the end-user. The self-growing process integrates several heterogeneous network elements into one access network providing continuous radio coverage to the end-user thereby enabling seamless mobile usage.

For the integration of 802.11-based networks in this self-growing process, devices have to be capable to act as a 802.11 STA in order to find 802.11 networks in their vincinity and to quickly establish a link with them to query for cognitive, self-growing capabilities via application layer services. As such link establishment might interrupt ongoing real-time communication using other technologies (due to a possible re-use of a single, reconfigurable transceiver chain), link set-up has to be conducted as quickly as possible.

|  |  |  |
| --- | --- | --- |
| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate | Less than 10 | Low |
| Media Load | Varies | Low to High |
| Coverage Interval | More than 10 sec | Low |
| Link Setup Time | Less than 100 ms | High |

# Prototypical Use Cases

## Use Case 1

|  |  |  |
| --- | --- | --- |
| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

## Use Case 2

|  |  |  |
| --- | --- | --- |
| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

## Use Case 3

|  |  |  |
| --- | --- | --- |
| Trait | Expected Value | Difficulty designation |
| Link-Attempt Rate |  |  |
| Media Load |  |  |
| Coverage Interval |  |  |
| Link Setup Time |  |  |

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