Out of the Fog:

Use Case Scenarios

Industry	Smart Cities
Application	Traffic Congestion Management



In the U.S. alone, the costs of traffic delays in 2015 included:

- 3 billion gallons of fuel wasted
- 7 billion extra hours sitting in traffic
- $160 billion, or $960 per commuter

Source: Texas Transport Institute 2015 study

Executive Summary

Traffic congestion is such a severe and growing problem that it has the potential to paralyze major cities, choking off growth and prosperity. Some cities are taking what commuters may consider drastic and expensive measures, like expanding toll roads or restricting the number of license plates issued.

The open architecture of fog computing gives municipalities a new weapon in the fight against traffic congestion. Fog has the flexibility to leverage traffic-related big data, which enables municipalities to take measures to alleviate congestion by connecting and analyzing previously unconnected infrastructure devices, roadside sensors, and on-board vehicles devices, in order to redirect traffic based on real-time data.

Challenges	• Traffic inflicts a high cost to cities: Lost commuter productivity from gridlock, slower emergency response and high carbon emissions. • Some factors influencing congestion, such as accidents and weather, are unpredictable. • Different city departments own pieces of the traffic problem; as a result, solutions are developed in silos, hindering information sharing. • Traffic-oriented data sources are bandwidth intensive and increasing in complexity.
Solution	• The open architecture of fog computing provides the flexibility to connect previously unconnected infrastructure devices, roadside sensors, and on-board vehicles devices. • Different authorities responsible for various traffic-related programs can set up fog networks to enhance connectivity, functionality or manageability for their applications. • To prevent information silos, fog gateways can share information across individual fog networks. • Fog nodes can lower the cost of equipment by supporting requirements such as security and storage – which can add to the cost, size and weight of cars, cameras, meters and more.
Technology	• Vehicle-based fog nodes consolidate data from all on-board sensors and connect to other fog nodes via specialized clouds, such as EMS clouds. • Roadside or local fog nodes collect real-time data along roadways and connect to other fog nodes. • Neighborhood and regional fog nodes that aggregate big data from roadside nodes to determine congestion and emergency responses.

The Choking Consequences of Urban Traffic Congestion

Traffic congestion is such a severe and growing problem that it has the potential to paralyze major cities, choking off growth and prosperity. Some cities are taking expensive and drastic measures, like expanding toll roads or restricting the number of license plates issued.

The consequences of escalating traffic congestion problems are wide-ranging, including:

- Causing millions of hours in lost productivity due to the inability of workers to get to their jobs on time
- Thwarting the ability of first responders to respond quickly to emergencies
- Increasing traffic-related accidents
- Delay in municipal services, such as trash pickup
- More carbon emissions from idling cars stuck in traffic or circling looking for parking spaces

Challenges for Alleviating Traffic Congestion

An estimated 60% of smart cities are investing in improving traffic-related services. Most of these cities are prioritizing investments that have a demonstrable ROI, such as:

- Updating roadway infrastructure (cameras and sensors) to catch traffic violations, which, in turn, contributes revenue to the city
- Creating smart parking on the street and in parking lots to capture more parking revenue

While the problems associated with traffic congestion are enormous, it may be difficult for city planners to justify expenditures that aren’t tied directly to revenue generation.

Traffic management spans multiple jurisdictions

Within each city, different departments will own pieces of the traffic problem. As a result, solutions will probably be developed in silos, rather than under a multi-year, cross-jurisdiction plan. These siloes can become obstacles to future information sharing and other integration initiatives.

Growing volume of data

Traffic sensing technology can provide revenue streams based on traffic calculations, yet challenges remain on how this bandwidth-hungry application can be added to an already strained network with limited capacity. How can cities build an infrastructure capable of absorbing, and making use of huge new sources of streaming data?

Complexity and range of traffic congestion problems

Some traffic issues are predictable, based on historical analysis (such as commuter or event traffic). Some traffic management issues, like accidents, are completely unpredictable. Even weather that affects road conditions can vary from somewhat predictable to completely unpredictable.

Key Features Enabled by Fog Computing

The siloed nature of city operations can present challenges for complex data transactions. The open architecture of fog computing gives municipalities the flexibility to connect previously unconnected infrastructure devices, roadside sensors, and on-board vehicles devices:

- Authorities responsible for different traffic-related programs can set up their fog networks at any time to enhance connectivity, functionality or manageability
- To prevent information silos, fog computing gateways (hardware or software) can be added to share information across individual networks
- A fog domain can be set up as a multi-tenant environment
- Fog node sensors can access both private and public fog and cloud networks

In Smart Cities, Which Cloud is the Destination for Traffic Information?

When people talk about communications between devices and the cloud, it suggests a relationship of many-to-one. In reality, municipalities will likely be working with multiple clouds associated with supporting traffic management. For example, there will be clouds for:

- Emergency Management Services (EMS)
- Metropolitan Traffic services
- Manufacturer services (supporting onboard devices and applications in vehicles for Internet, phone, and infotainment systems)
- Service provider services (also supporting onboard vehicle devices and applications for information such as maps and driving conditions)

City planners and architects need to take all of these clouds into consideration when trying to map data flow from a myriad of devices to multiple special-and general-purpose clouds.

This can create a complicated matrix of communications that can result in duplication of information and potentially lead to confusion and conflict. It can also create dangerous silos and delays in response.

Fog computing provides the ability to create any-to-any communications paths without disrupting existing edge-to-cloud communications. Data stored in fog nodes can also be uploaded to the appropriate cloud or to multiple clouds to bridge silos.

Roadside or local fog nodes. Roadside or local fog nodes can collect data from all kinds of sensors installed along a roadway: CCTV and IP cameras, electronic signage, traffic lights and roadside lighting. These roadside fog nodes can perform local analysis and send this information to traffic-related applications to trigger an automated emergency response, such as:

- Flooded roads ahead: take next exit
- Water on road: slow down

The roadside fog nodes can also analyze data locally and send that information to the neighborhood or regional fog nodes for correlation with other data. If there are fog gateways in the network, raw or filtered data can be forwarded to one or more clouds for further analysis.

In addition, fog nodes can lower the cost, size and weight of individual devices or equipment by providing additional functional requirements such as security and storage re clouds for further analysis.

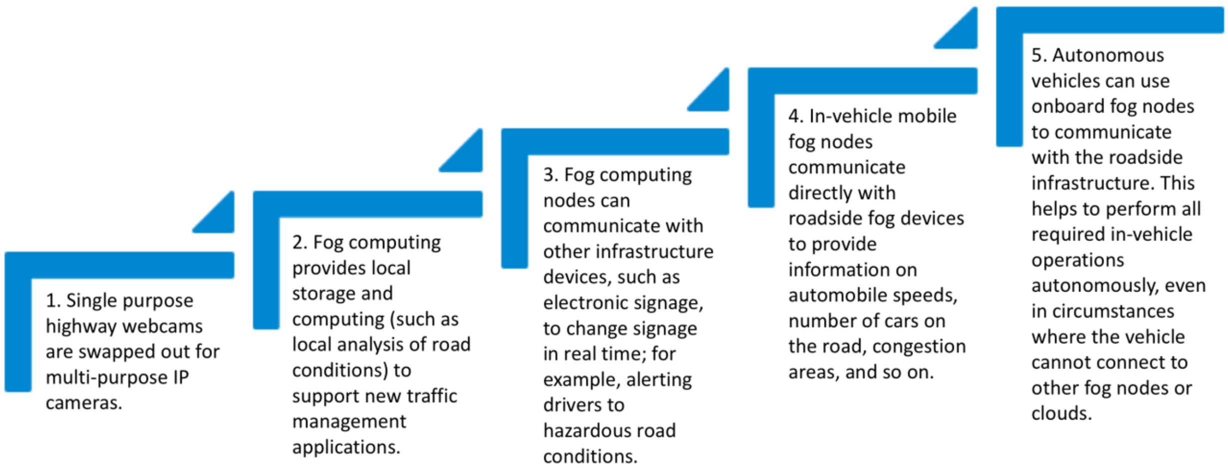
Neighborhood and regional fog nodes. City planners and traffic analysts can aggregate data from multiple local nodes to give city officials and emergency responders the ability to coordinate traffic from one local area to another.

For example, if there’s an accident on a specific roadway, this might trigger a sequence of actions:

- Use electronic signage and EMS apps to alert cars to slow down
- Tell cars which lanes to avoid, so they can start moving out of the way minutes or miles away from the accident scene
- Help clear the road for emergency responders
- Use lights and signs to divert traffic to alternate roads to prevent a traffic jam on a single secondary road

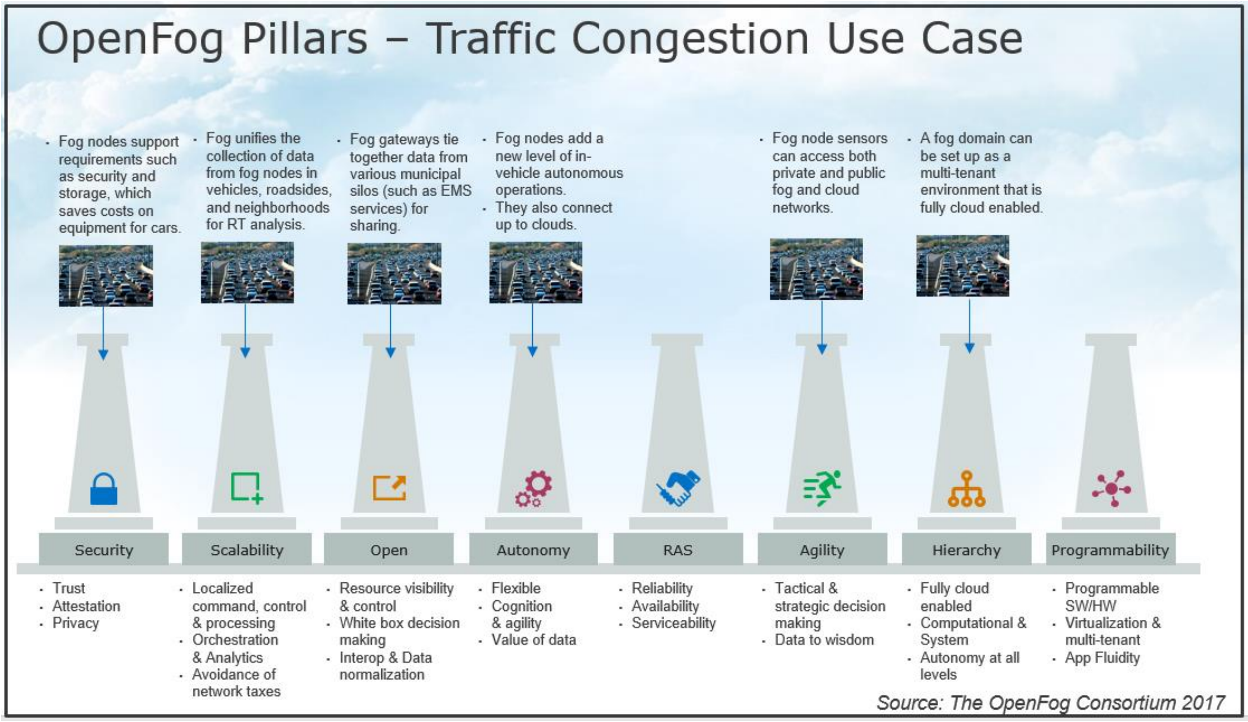
By having a view that is elevated above a local traffic congestion problem—whether it's an accident or road flooding—city officials can respond quickly and decisively. In fact, traffic plans can be dynamic traffic routing scenarios created in advance. They can even be predictive, by using historical data to anticipate and alleviate congestion before it happens. In addition, the information from neighborhood and regional fog nodes can be analyzed, filtered or summarized and sent on to one or more clouds.

The cities will also get congestion relief from the vehicles themselves. As new cars roll off the assembly line with an ever-increasing number of onboard sensors, the cars are increasingly able to respond to internal and external information—such as proximity to another vehicle—to trigger an instantaneous avoidance response. By installing fog nodes in vehicles, manufacturers can add a new level of in-vehicle autonomous operations that connect with other devices. In addition to making the vehicles safer and more likely to avoid traffic-causing accidents, the municipalities can connect in-vehicle communication with roadside sensors, aggregating the data to provide a larger view of traffic and road conditions.



Fog computing can make it easy for city planners to extend the capabilities of current investments to accommodate future applications.

An Architectural View



What is Fog Computing?

Fog computing is a system-level horizontal architecture that distributes resources and services of computing, storage, control and networking anywhere along the continuum from Cloud to Things.

- **Horizontal architecture:** Supports multiple industry verticals and application domains, delivering intelligence and services to users and business.
- **Cloud-to-Thing continuum of services:** Enables services and applications to be distributed closer to things, and anywhere along the continuum between Cloud and Things.
- **System-level:** Extends from the Things, over the network edges, through the Cloud, and across multiple protocol layers – not just radio systems, not just a specific protocol layer—not just at one part of an end-to-end system, but a system spanning between the Things and the Cloud.

About the OpenFog Consortium

Traffic congestion management for smart cities is just one of many industry use cases whose commercial viability will depend on fog computing in order to achieve the rapid response, bandwidth and communication necessary in advanced digital applications.

The OpenFog Consortium is a global nonprofit formed to accelerate the adoption of fog computing in order to solve the bandwidth, latency, communications and security challenges associated with IoT, 5G and artificial intelligence. Our work is centered around creating a framework for efficient and reliable networks and intelligent endpoints combined with identifiable, secure, and privacy-friendly information flows in the Cloud-to-Things continuum based on open standard technologies. For more information, please contact us at info@OpenFogConsortium.org.