

# Thailand Royal Irrigation

## The World's Longest Wireless Mesh Network

### Background

The Royal Irrigation Department of Thailand, founded in 1904, is a government agency largely responsible for the development and maintenance in the country's main irrigation systems. The need for water is an essential factor in the national development of Thailand in every aspect. The construction of water resources in various scales and types cover all the regions of the country in a vast and systematic water management system.

The mission of the Royal Irrigation Department is four fold:

- Develop basin water management
- Use sustainable systems to monitor water management effectively
- Promote water management
- Prevention and relief of disasters caused by water

### The Challenge

The Ping, Wang, Yom, and Nan rivers start in the mountains in the northern part of the Kingdom of Thailand and flow south. They meet at Nakhom Sawan to become the Chao Phraya River. The Chao Phraya, the principal river of Thailand, flows south through the nation's fertile central plain for more than 231 miles (372 km) and empties into the Gulf of Thailand. The severe flooding that occurred in 2011 was ranked as the world's fourth most costly disasters of that year with severe impact to human life and the economy of Thailand. The Chao Phraya Basin's natural features, as well as its size, made it the most important area for irrigation development.

The Chao Phraya River Basin is home to a large population and is economically important to the country. Large cities, such as Bangkok, sit near its shores. This area has a long history of agricultural use and modification:

- Canals for transportation
- Dams to mitigate flooding
- Dams and dikes to divert water to irrigate crops

The rainfall varies greatly, and the population is dependent on the variable, seasonal monsoon rains. The people need to have current and at times constant data to be able to plan for effective water management and have sufficient warning before floods occur.

Each year the reigning King of Thailand, Bhumibol Adulyadej, takes a journey up the Chao Phraya River to get a better understanding of the well-being of the Thai people and to get a first-hand look at the river and the massive agricultural fields it feeds.



Figure 1: Chao Phraya River



The world's longest wireless infrastructure network from Firetide protects the people of Thailand by delivering live HD video and real-time telemetry data of river water levels for early flood forecasting.



As the King aged, he was unable to take this annual trip up the river, but still wished to monitor rising water levels during the monsoon season. This would provide the Thai people with an early flood warning system, alerting them to keep a close eye on the country's agricultural crops along the river. To acknowledge the King's birthday wishes to protect the citizens and crops, Mr. Chachawal Punyavateenun, Project Creator and Deputy Director General of Thailand Royal Irrigation, and Dr. Nat Marjang, Project Manager and Faculty of Engineering, Kasetsart University, collaborated to deploy a video and data network that allows monitoring of the river basin.

## Solution Requirements And Testing

The Chao Phraya River, being very long, poses a physical and technical challenge of broad scale to connect all the sensors and cameras planned for the project. The real-time video monitoring system and live telemetry data network developed for this project would need to enable citizens, security, and agricultural officials to monitor 372 km (231 miles) of the flood-prone Chao Phraya River Basin.

The Royal Irrigation Department needed a technology solution that could meet both the technology requirements, but also address the rigorous physical requirements of terrain, harsh weather conditions and coverage distance.

The selected solution needed to support the following requirements:

- 240 Mbps to support live HD video feeds, river water levels and telemetry data for real-time flood forecasting and historical data collection.
- 24/7 network availability, which could be achieved with redundancy; the network would be used to monitor critical flood zones and any downtime to the system could result in drastic consequences.
- Supervisory Control and Data Acquisition (SCADA) integration to monitor their system's operations.

Thai authorities worked for months, carefully researching and selecting the optimal technical solution to meet this significant challenge. Several options were evaluated and tested:

- Conventional technology solutions: such as ADSL, 3G, and Satellite communication were explored, but following extensive trials, the technologies tested were not able to meet the technical requirements set forth.
- Point-to-point and point-to-multipoint wireless technologies: also tested, but were not able to deliver adequate results over the minimum required distances of this challenging network.
- Fiber: was also considered, but budget, risks, and the time-to-deployment for such a project were not realistic; a cabled network might have taken several years to complete.

After exhausting other options, the customer requested testing a Firetide wireless infrastructure solution. The trial of the world's first public safety wireless mesh network, capable of delivering live high-definition (HD) wireless video feeds of river water levels and telemetry data for real-time flood forecasting and historical data collection, was deployed and ran for one month to confirm the reliability of the Firetide solution.

Planning was the key to success in this process and trial.

## Planning The Trial

The trial goal would entail setting up a link between the Royal Irrigation Headquarters and a location with 2 cameras about 70 km away. The setup is as shown below.



Figure 2: Trial setup

Planning for every link of the trial started by selecting the locations where the nodes and antennas would be installed.

Once the locations were selected, computations needed to be done to make sure that the links would operate at maximum performance.

In this trial, the longest link would be 33 km. It was decided to use 3 feet 31dBi Gain antennas.

In the map illustration here are the locations that were selected based on the computations and on the site constraints.

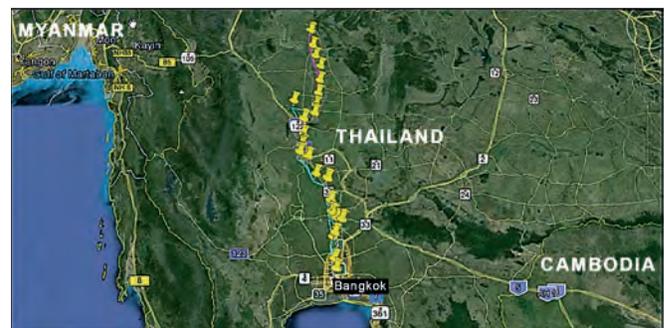


Figure 3: Location of the Nodes

Once the locations were selected, the next step was to compute the height of the antennas. RF line-of-sight being different from visual line-of-sight, a study had to be done for every link. Taking into consideration the distance between the antennas, the frequencies in use, the land elevation and the obstructions between the locations, the minimum height of the antennas was computed. An example is shown in Figure 4 for the longest link in this set up.

Input	Output
Frequency: 5800 MHz	Equivalent Earth radius: 8472 Km
Atmospheric refraction: "k factor" (typical 1.33) 1.33	<b>Equal Antenna Height Solution:</b>
Percent of 1st Fresnel Zone (typical 60%) 60%	Radius of 60 % 1st Fresnel Zone at mid point: 12.4 meters
Link distance: 33 Km	Height of both antennas for Fresnel Zone clearance: 28.4 meters
<b>Antenna Heights:</b>	<b>Minimum Clearance Point:</b>
Site 1: 29 meters	Distance from site 1: 17 Km
Site 2: 29 meters	Clearance between Earth and FZ: 1 meters
<b>At arbitrary point P:</b>	<b>Clearance at point P:</b>
Distance from site 1: 3 Km	Radius of 60 % 1st Fresnel Zone: 7.1 meters
Distance from site 2: 30 Km	Clearance between Earth and FZ: 16.6 meters

Figure 4: Fresnel Zone computation for 33 km link

This shows that 28.4m is the absolute minimum height of the antenna for this link. However, over 33 km it is highly possible that buildings and land elevation can be in the Fresnel Zone.

Using Google Maps, it allowed us to verify that no natural obstacles were present on the link. The example below shows a sample elevation profile study on a specific link.

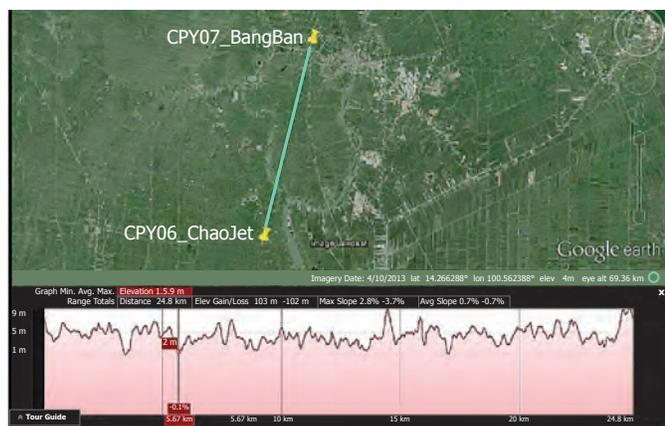


Figure 5: Elevation profile

After further study of the land elevation conditions, site surveys were conducted to verify that no man-made or natural objects would interfere with the Fresnel zone.

Once we were sure that nothing would affect the RF signal, the antennas were installed in the last 10m of a 60m high tower on one end, and the last 5m of a 45m high tower on the other end. This ensured that all the antennas were installed with an extra 10m of clearance for trees and other buildings.

## Deploying The Trial

With all elements of the planning completed, the next phase of installing the equipment could begin. A key for such an installation is to achieve good alignment for the view between locations. That is where basic tools such as a compass and binoculars are necessary to help achieve alignment needed to get the link up. Once the link is up, Firetide's built-in antenna alignment tool helps to fine-tune the link to the highest degree and get as close as possible to the target RSSI.



## Testing The Links

With the links installed and aligned to what has been computed, tests were conducted to confirm that the throughput and latency were as expected and that the HD video would not have any trouble reaching the command center using the Mesh.

The tests were executed on the trial links going from one end of the trial Mesh to the other end. This would span over 4 hops, and about 70 km.

During one month, there were 2 cameras at the far end of the Mesh at the CPY 7 location, and 1 camera at the CPY3 location.

With this setup, the results that the links produced were excellent, showing maintained performance over the distance of the link and using multiple hops. As tests were performed using the non-MIMO-capable Firetide 6000 Series, the throughput showed an average of 20 Mbps and most importantly smooth video.

The results demonstrated exceeded the expectations of the Royal Irrigation Authority, allowing the HD cameras that would be used for the project to stream their videos effortlessly to the video server.

## Trial Results

### Firetide Private Wireless Broadband Network Solution Delivers Live HD Video Reliably Over Long Distances

The results shown in the previous section and the efficiency of the solution over long distances were enabled by Firetide's patented AutoMesh™ software protocol. It proved to be precisely the solution that the Royal Irrigation Thailand authorities had been seeking. Nowhere is safety more critical than during major natural disasters that involve the lives of millions of people and potentially billions of dollars of property damage.

Over the course of the trials, the authorities were particularly impressed by the:

- Wireless performance trials which demonstrated that the Firetide solution reliably delivered live HD video to the control center up to 70 km away
- Robust redundancy to provide 24/7 network availability
- Ease of deployment for a very large-scale project
- Timeliness of deployment
- Ease of system configuration

The customer selected the Firetide HotPort™ 7000 Series intelligent wireless infrastructure nodes as the MIMO capabilities would allow them to expand the capacity and ensure that expansion of the network over time would not be an issue.

The customer is now using MIMO 20 MHz bandwidth for the links that have been used for the trial and UDP throughput results as most recently tested are as follows:

Link Name	CPY 3 to CPY	CPY 4 to CPY 6	CPY 6 to CPY 7
Distance	12 km	3 km	6 km
Antenna	3 ft Parabolic 31dBi Gain	3 ft Parabolic 31dBi Gain	3 ft Parabolic 31dBi Gain
UDP Throughput	73 Mbps	61 Mbps	60 Mbps

Table 1: Throughput of the links

## Complete Solution Deployment

### Firetide's Patented AutoMesh is the Key Enabling Technology Designed to Handle Unique Demands of Royal Irrigation Project

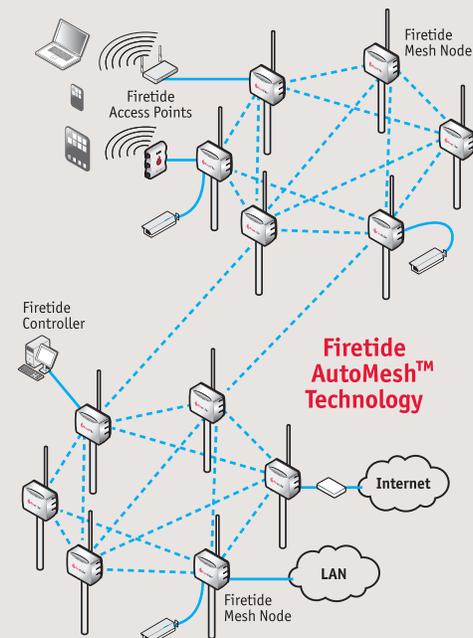
#### AutoMesh Performance Meets Distance Challenge

Firetide's unique AutoMesh technology allows for sustained performance over multi-hops while adding only 0.9ms of latency for every hop. This enables the video to flow from the edge of the network to the control center and proved to be the most important feature for this project.

In order to have logical entities that are easily manageable, three mesh networks were designed for a total length of 380 km (236 miles) and

## Firetide AutoMesh

Powering all Firetide products, the patented AutoMesh technology is a unique wireless networking platform designed to handle the demands of video and mobility. AutoMesh also delivers environment and multi-service awareness. AutoMesh enables the following unique features and benefits including redundancy and multi-hop optimization that were especially crucial to the Thailand Irrigation project. AutoMesh enables zero-down time carrier grade reliability over wireless, with seamless failover required for mission critical applications such as the Irrigation project. Additionally, the patented MPLS-type FMRP low-overhead routing protocol makes it the only solution in the market with no performance degradation with 15 wireless hops. Further, less need for fiber lowers total cost of ownership and enables rapid deployment.



total links distance of 550 km (342 miles). The three meshes would be connected together to form this network. The details are as follows:

- Mesh 1 on a total distance of 120 km (75 miles)
- Mesh 2 on a total distance of 80 km (50 miles)
- Mesh 3 on a total distance of 180 km (112 miles)

### AutoMesh Redundancy Meets The Reliability Challenge

A critical criterion for this project is the fact that it is used to monitor critical flood-prone areas; any downtime to the system could lead to dire consequences if downtime were to occur at an unplanned time. The Firetide private wireless broadband network solution based on AutoMesh technology introduces redundancy to the whole network.

### Wireless Redundancy Through Redundant Path

The design of the solution introduced redundant path. This means that for every single critical location in the system, there are at least two paths to get to the consumer of the data. In this case, from every backbone node, there are at least two paths to the video server. So if obstructions occur and a link happens to go down, the camera is still viewable.

### Wired Connectivity Redundancy

Due to the intrinsic design of the Firetide architecture (distributed switch), connecting two cables from a switch to the same Mesh will lead to a Spanning Tree Protocol (STP) loop. The Firetide solution introduces GateWay Servers (GWS) and Network Gateway Interfaces (NGI) to solve this problem.

Two GWS in the Mesh are connected to the external switches; they are configured as active and standby. The active GWS is the one transmitting the data between the Mesh and the external switch, while the standby is ready to take over if anything happens in the connection between the primary GWS and the external network. This architecture prevents the creation of STP loops, while maintaining control over how the data is flowing.

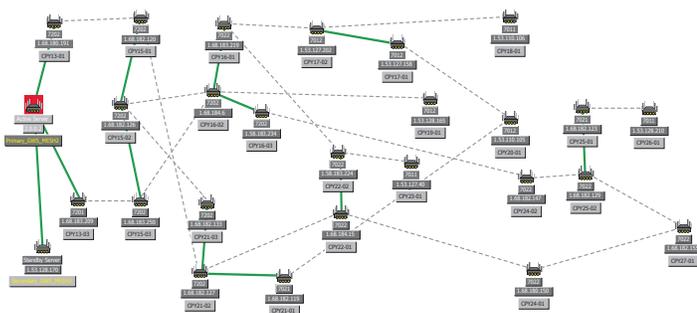


Figure 6: Redundant Network

The NGIs are mesh nodes that are configured to specifically work with the GWS, they are aware of which GWS is active and forward the traffic towards the active GWS.

## Project Architecture

The combination of the solutions for those challenges creates a complex architecture as detailed below.

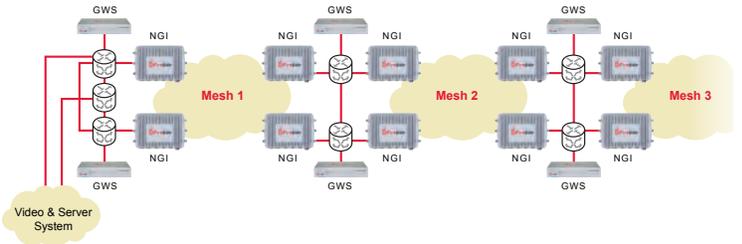


Figure 7: Architecture Overview

In this diagram, the Firetide 7020 Mesh Node represents the NGI and the Firetide 7010 Mesh Node represents the GWS. The links between them are implemented through standard switches.

## Firetide Solution Sample Test Results

### Sample Test For Single Link With 150 Mbps Udp Throughput For 26 km Link

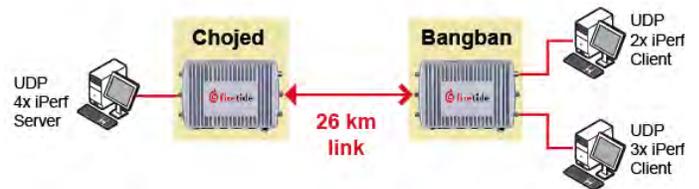


Figure 8: Test 1 Setup

### Test Setup

The test included three high-performance laptops, 26 km distances with 40 MHz MIMO single link. The test would be running 5 sessions with 30 Mbps for each session. Each session would be opened on a different UDP port.

The two nodes are installed on 45 meter poles; Fresnel Zone calculation gives a clearance of 24 meter for this installation.

## Sample Test For Redundant Link With 240 Mbps UDP Throughput @ 31 km Links

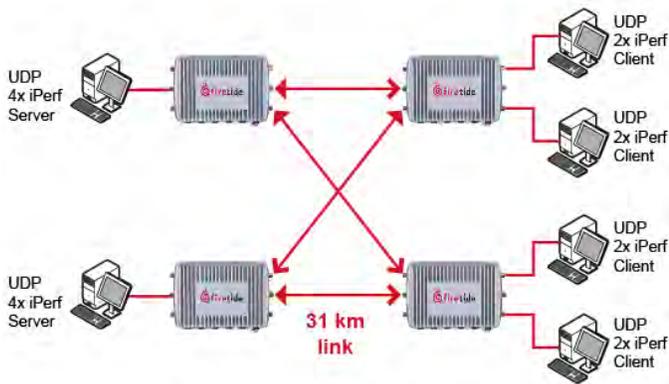


Figure 9: Test 2 Setup

### Test Setup

The test included six high-performance laptops, 31 km distances with 40 MHz MIMO redundant link, running 8 sessions with 30 Mbps each session.

The four nodes are installed on 45 meter poles; Fresnel Zone calculation gives a clearance of 19 meter for this installation.

## Other Success Factors

Quality of installation is another key to the success of the Thailand project and others like it. For this project, Firetide instructed the installation partner to take particular care when performing the physical installation. For example:

### Weatherproofing the RF connectors

It is crucial to do the weatherproofing as thoroughly as possible. If water were to leak inside the equipment, the performance may drop and investigations under these conditions can take a long time to determine the source of the problem.

### Redundancy of the power source

When installing in remote areas where the power source is not 100% reliable, having back-up is critical. This will allow the network to operate even when power is lost temporarily. In this project, the systems integrator provided UPS and additional solar panels at each of the locations.

### Quality of the tower installation

In order to guarantee the throughput of our equipment, we require it to be installed on solid poles/masts to reduce the shaking that can result in link instability. In this project, particular care has been taken for civil works in order to ensure that all the masts installed would be of the highest quality.



## Summary And Impact

The current Firetide wireless network consists of 64 Firetide HotPort 7020 wireless Mesh Nodes and 27 cameras. Deployment of the Firetide wireless video network was completed in less than one year, whereas a wired network would have required two to three years to complete. Furthermore, the flexible Firetide wireless network can be easily expanded for future uses and is much more cost-effective compared to deploying a wired network.

After the two pilot deployments done in collaboration with our local partners CommExpress (Thailand) Co. Ltd. and Embes Technology (Thailand) Co. Ltd., their teams successfully completed the main deployment of Firetide Mesh Nodes along the Chao Phraya River. Each node links wirelessly to adjacent nodes upstream and downstream to form the mesh network. With link distances, or hops of 20 to 33 km between nodes, the system delivers up to 240 Mbps bandwidth with less than a one millisecond delay per hop for smooth, real-time data and video delivery for the entire length of the network. The Firetide private wireless broadband network also provides full redundancy so if a link fails, another link takes over immediately with no noticeable interruption in service. The actual combined length of all links, including redundant links, deployed within the 372 km geographical distance totals 550 km or 341 miles, making the Firetide network the world's largest and longest wireless mesh network.

With the Firetide solution in place the Royal Irrigation Department can now:

- Remotely monitor along the Chao Phraya River in real-time
- Remotely control water gates and monitor the remote changes in real-time
- Increase public use of the system for their improved welfare

## Future Growth

The Royal Irrigation Department looks forward to other future projects, such as:

- Live rain forecasting
- Automatic flood prevention actions



## References

World Water Assessment Programme. 2009.  
*The United Nations World Water Development Report 3: Water in a Changing World.*  
Paris: UNESCO Publishing, and London: Earthscan.

***In 2013, Thailand Royal Irrigation Department was named a Computerworld Honors Laureate for its Wireless Flood Management Network, enabled by Firetide technology.***

## About Firetide

Firetide, headquartered in Silicon Valley, is the technology leader in private wireless broadband networks based on mesh technology. Powered by its patented AutoMesh™ technology, Firetide solutions meet the stringent demands of high-definition video, voice and data applications for public safety, transportation and industrial solutions. Founded in 2003, the company has more than 10,000 customers in 40 countries around the world, including Seoul Metropolitan Rapid Transit, the City of Chicago, and a citywide Intelligent Transportation System that covers 185 square miles in Scottsdale, Arizona.



Case Study

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