Response to

Power Sector Transformation

Grid Connectivity and Capabilities Work Stream

Advanced Grid Capabilities and Questions for Stakeholders

Dated August 20, 2017

In response to technical meetings held on May 9th, June 15th and July 31st, stakeholders have been invited to provide responses to a number of questions. Stakeholders may choose to respond to a selection of the questions of which we are responding to Question #6:

6) Development of a shared communications network among existing wireless network operators, the electric utility, and other infrastructure providers can significantly reduce capital costs for ratepayers. Please provide any considerations to inform formation of a shared communications network.

Response:

We are the Agile Fractal Grid and have originally been chartered to assist the rural electric cooperatives in providing advanced grid capabilities and communications infrastructure support for them in their region of the country. Some of the concepts used to form the shared communications network in this vast national coverage area may be useful relative to the statewide power sector transformation contemplated in Rhode Island across the state.

By way of background, there are some 960 cooperatives that provide electric power to some 42 million Americans over the sparsely populated coverage area totaling some 74% of the land mass of the United States. The Agile Fractal Grid was formed to address three specific needs for the hybrid electric and communications grid in this region:

1) Participate in the decentralization of the real-time power grid control into an Agile Fractal Grid for resilient and secure operations – this using a shared communications infrastructure supporting multiple public, commercial, and industrial needs.

2) Incorporate a cloud-based "Digital Marketplace" for supporting the numerous over-the-top third-party providers of distributed electric controls systems, communications services, and various community services in the areas of public safety, education, and medical applications.

3) Incorporate a Security Fabric designed in conjunction with the Department of Defense for supporting the emerging Industrial Internet to protect all communications between the elements.

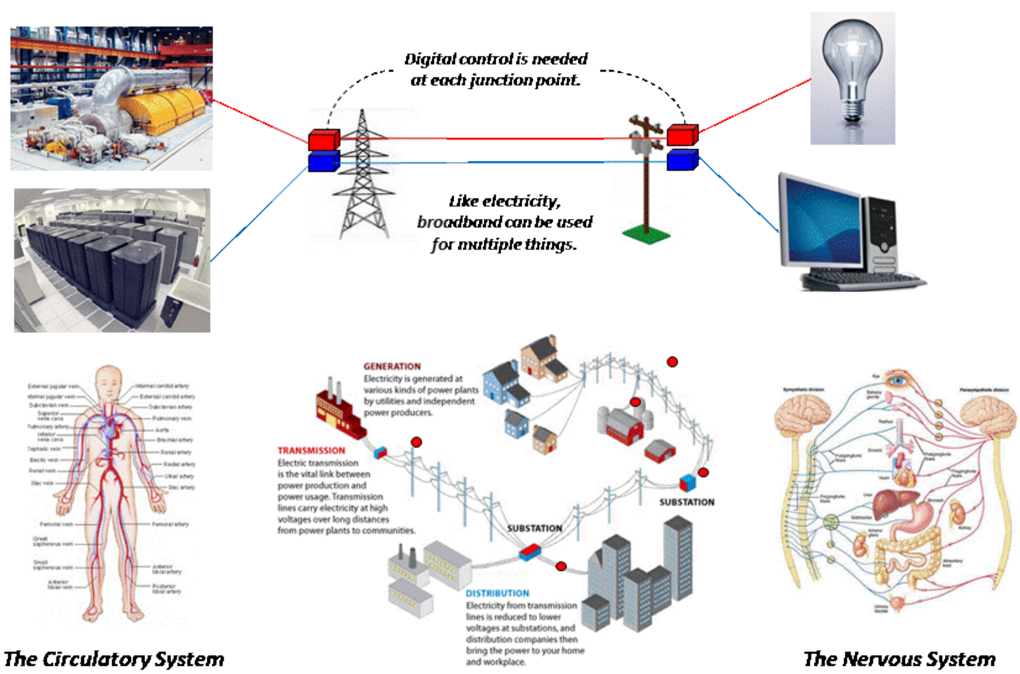
The Agile Fractal Grid is not prescriptive as to who the service providers are that use the shared infrastructure, but many of the goals sought by Rhode Island during the planned Power Sector Transformation can be supported by the various third parties that are a part of the AFG Community of Practice. You will already find numerous AFG providers that address the following goals outlined in detail in the attachments to the request:

- Security and Resiliency
- Facilitating Consumer Choice
- Integrate Renewables
- Control Energy Costs
- Workforce Management
- Transactive Energy Market Functionalities

A close scrutiny of the published list of the Rhode Island functionality and capabilities matrix will show fairly comprehensive support by current partners. The current service provider list is fairly wide, but there are no exclusive arrangements and at least one new member of the Community of Practice is added each week.

The Natural Patterns Emerge

A good way to visualize the pattern employed by the Agile Fractal Grid is shown in the following diagram:



Electric power distribution and broadband communications are like Siamese twins!
(They can't go anywhere without each other.)

Systems of infrastructure tend to grow organically as they are needed. But over a long period of time of trial and error and survival of the fittest, certain patterns tend to emerge as resilient and most efficient. All the other experiments tend to die out along the way. The analogy to be observed from nature here is that the electric grid will tend to operate in much the same way as the human body's circulatory system, and the broadband approaches will tend to operate with the same purposes as the human body's nervous system. Both are quite different in purpose and delivery technique, but both are so highly dependent on each other that they always run together to all the same points. Note also the development of the limited autonomic nervous system needed to respond instantly for protection purposes when it would take too long for the brain to realize that action is needed for protection purposes.

If we envision the pattern showing where we are headed with our optimizations ever present before us, we can cause each project we undertake begin to flesh out the vision even though each incremental step along the way is only a partial solution. And each step must also try to heal any imperfections that were accidently introduced in prior steps. Such is the usefulness of the "agile" servomechanism that should be used in implementing new capabilities.

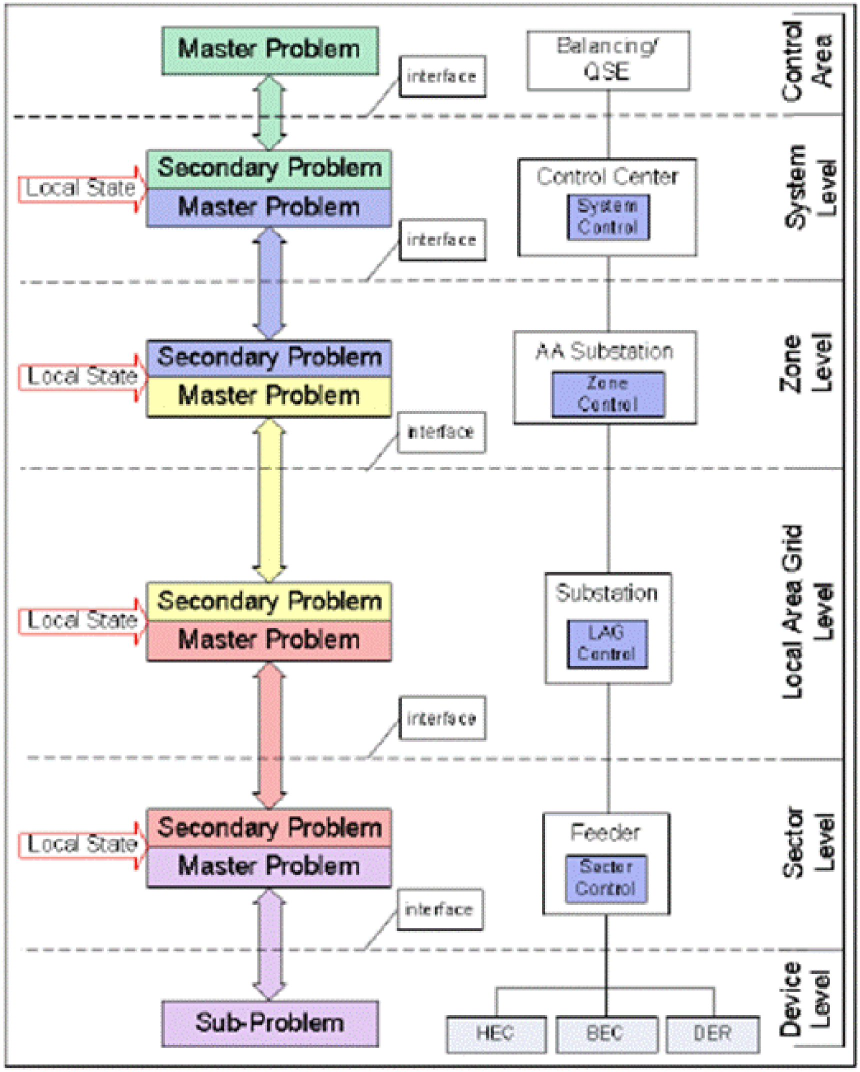
Decentralized Electric Power Controls

The communications infrastructure required for the electric power controls in the targeted coverage areas is meant to implement what is called in the industry as a Laminar Control Node structure for the decentralization needed when introducing renewables into the distribution grids.

This pattern tends to emulate nature by introducing a "fractal" approach to situations where decentralization of the same function is desired, but where some level of limited cooperation between the parts is also useful. This cooperation between the parts is reminiscent of how the rural electric cooperatives work with each other for survival and efficiency. It is well known that this culture of human interaction is why we now have electricity to virtually every home in rural America now when previously in the 1930's less than 10% of the homes in rural America had electricity. All we are doing here is applying the same technique as chapter 2 in the same story as we begin to proliferate the high-speed broadband infrastructure.

Fundamentally, we are introducing the same decentralization pattern for electric distribution that was used for decentralizing the old Bellcore hierarchical pattern for communications into what is now widely known as the Internet.

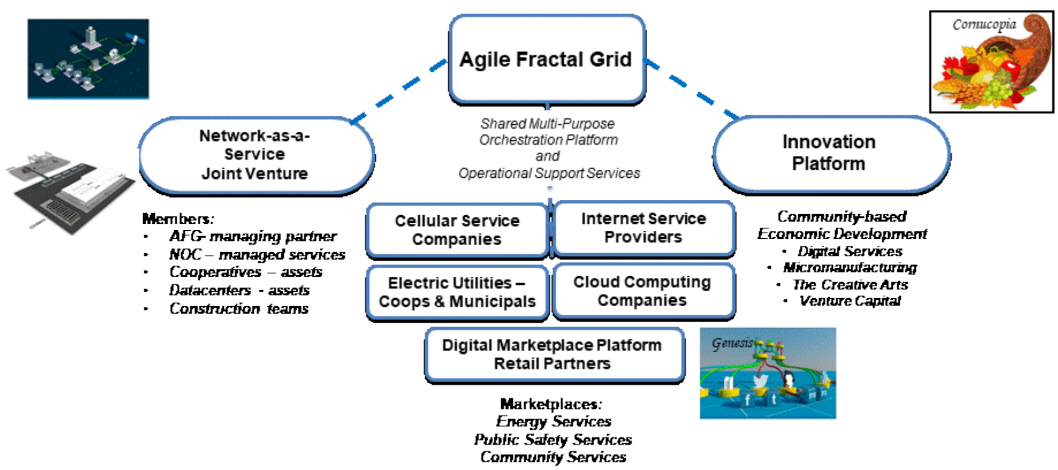
The following diagram shows the layering of real-time control logic superimposed over the current topology of the electric transmission and distribution architecture:



In this approach, most of the sensitive control is delegated to the bottom edge closest to the consumer. Each level is responsible for taking care of business as it can most clearly see. It considers advice from above, but it does what needs to be done locally, because it has the best vantage point for the local urgencies. It always reports upward what decisions have been made locally for analytical purposes. But given the inclination to go along with advice from above given the lack of a reason to do something else, the whole stack of cooperating levels tends to move much like a flock of birds in a smooth and unifying pattern toward the generally desired optimal outcome. Very smooth, very graceful, and very effective.

The Structure of the Public Private Partnership

The way that the Agile Fractal Grid is structured, it has formed a public – private partnership (PPP) called Network as a Service (NaaS). In this approach, the NaaS is made up of different groups that own various resources including dark fiber bundles and are making some of the strands available using indefeasible rights of use for the shared communications infrastructure. The owners of the fiber are of course compensated for the use of their assets with monthly operating compensation, but the NaaS coordinates the use of these shared resources with a platform used for the benefit of service providers that want to use them for over-the-top services. Rhode Island's OSHEAN middle mile network could form the backbone of the statewide shared communication infrastructure if arrangements could be made for extending it and supporting the AFG NaaS across the state.



These service providers tend to be cellular wireless companies that want to use the shared infrastructure to deliver mobile services in areas that would otherwise be uneconomical. In areas that are already supported to some extent, the shared infrastructure allows for densification of coverage so that bandwidth capacity for higher speed services can be vastly expanded.

Internet service providers can use the shared infrastructure to expand their reach to homes and businesses on an Open Access basis. This allows for specialty providers to spring up for unique services that might not be economical to deliver if the Internet service provider had to overlay the region with separate communications infrastructure. There is no need to do this with the shared environment.

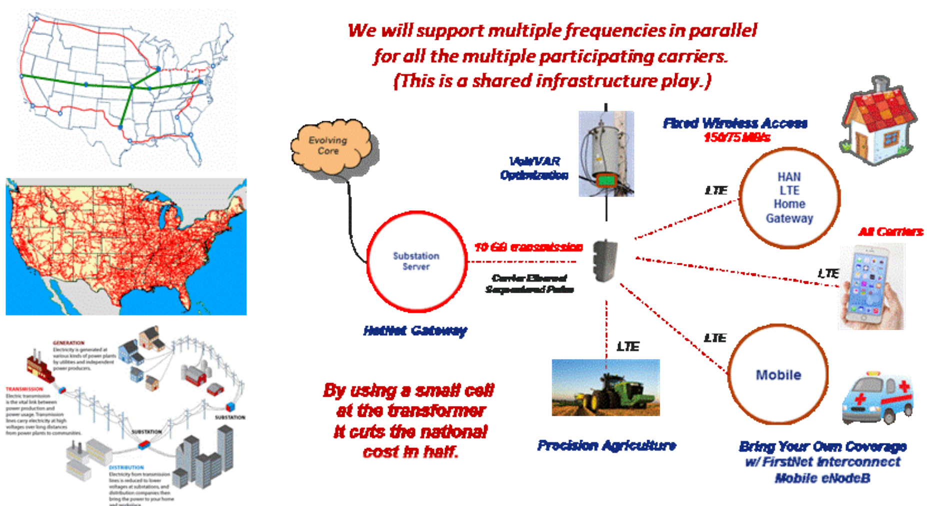
We have already discussed the pattern of using sequestered communications for electric power instrumentation and controls. Meter reading, volt/VAR controls from the neighborhood transformers, and Transactive Energy purchase and sale of demand response and distributed energy resources local generation are part of the AFG partner services.

The AFG also provides support for a constellation of innovation centers across the United States. Rhode Island's own Business Innovation Factory could be used to support this constellation in the Rhode Island region. The Cornucopia constellation supports both technical and mechanical innovation. It also has unique support for the passions of the interdisciplinary arts as is exemplified at the headquarters of Google, Facebook, and other platform centers of excellence.

The Open Access Network

The AFG provides for a fiber / wireless approach to supporting wholesale communications services to retail service providers. The AFG has no subscribers itself, but instead prepares infrastructure and wholesale transport available to others who provide the actual end-to-end services to all of their own subscribers in the area.

The AFG will expand incrementally to support a national core network for the United States incorporating some 13 interconnect nodes for direct connection to national and global communications networks for private line services, and also to various Internet Exchange Points for direct Internet access.

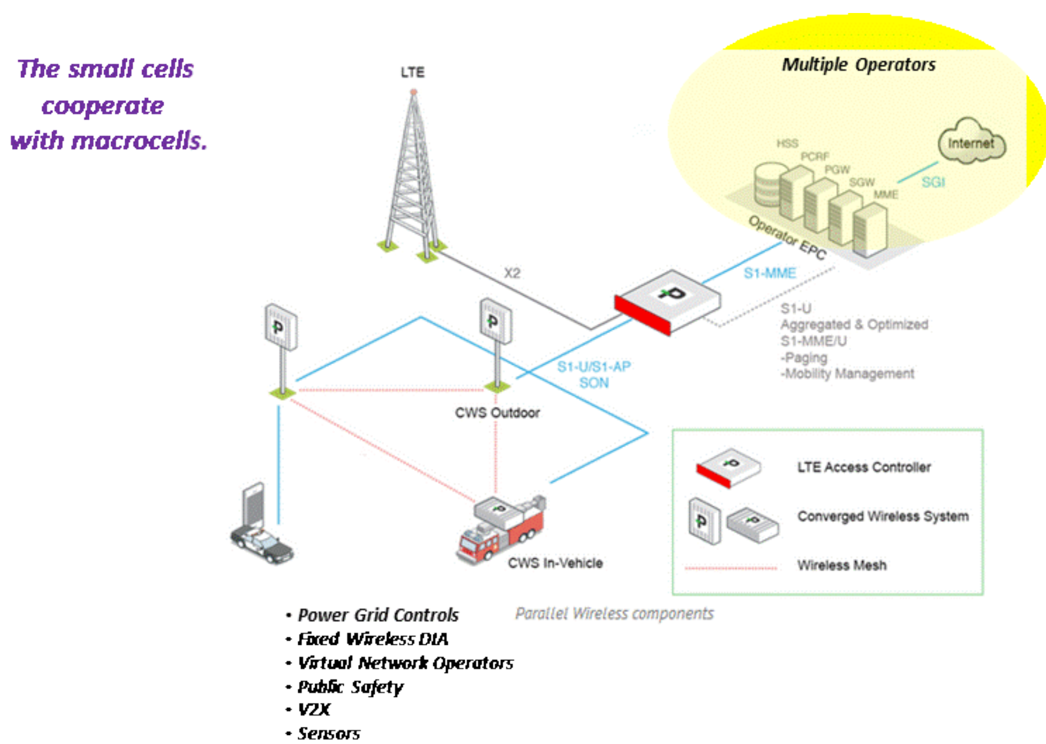


Electric substations form strategic nodes in the national shared infrastructure takeout networks. Substations are where high voltage electric transmission lines attach to transformers for medium voltage electric distribution safe enough to run throughout the community to homes and commercial buildings. The core network connects to local substations through a variety of regional fiber networks supported by national communications providers, electric transmission providers, and stimulus funded regional fiber networks. Open access LTE eNodeB gateways are located at the substations to serve all carriers who are sharing the infrastructure. Fiber runs along the electric utility poles in the communications zone to each of the poles where neighborhood transformers are placed to step medium voltage electric power down to lower voltage suitable for powering homes and business buildings.

In the AFG model, the device placed underneath the transformer has multiple purposes:

- It can be used to house the instrumentation needed to measure electric power at this edge of the network. This seemingly simple task provides for over 750 different measurements at the edge for precision smoothing and optimization of local power flow.
- The device is also a multimode small cell capable of independently supporting up to a dozen different wireless service providers from the pole.
- Mobile wireless services would include access services for mobile LTE carriers using their own licensed spectrum.
- Fixed wireless services can also support lightly licensed spectrum for lower cost high-speed reach to homes for Internet access.
- Public safety wireless services can be supported by an independent path using the new Band 14 FirstNet service.

The following diagram describes the typical shared infrastructure support for wireless services:

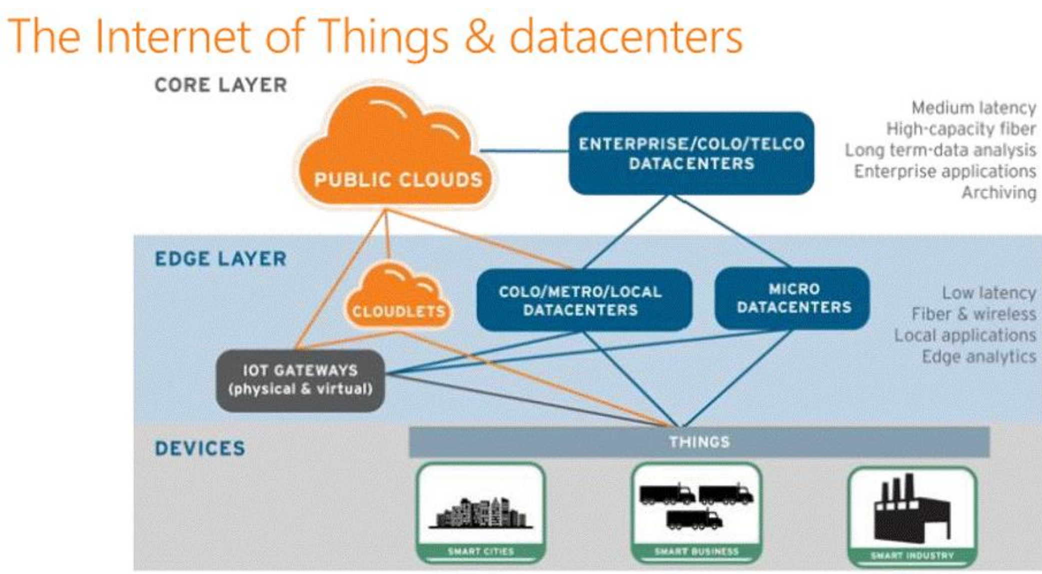


For a community, there tends to be a HetNet gateway head end for aggregating the fiber and wireless shared services. Note that the primary reason for this gateway is the support of all of the radio access network small cells in the neighborhood, but the small cells are good citizens and fully cooperate in a subservient way with any existing macrocell towers that may already be serving the local area.

It is interesting to note that there are also mobile versions of the multimode small cell that can be placed in emergency vehicles to bring five bars of coverage to the scene of emergency incidents for first responders. Clarity of communications at the scene is a high priority for all involved in emergency operations.

Support of Edge Computing

The so called Internet of Things is very much a reality for the decentralized control of the electric grid, but it is also an emerging need for specialized types of situations where extremely low latency responsiveness is needed for machine protection, or human gracefulness. The AFG supports this need for low cost local computing support at the edge, both for industrial control of the grid, but also for commercial support of other edge applications.



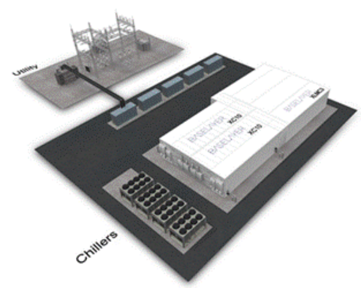
The AFG operates small computing pods at neighborhood transformers, substations, and certain other aggregation points in communities where useful in addition to direct connection to major cloud datacenters and large enterprise datacenters.

Retail service providers can arrange to run virtual machine or containerized microservices in these miniature "fog" computing pods if it is useful for them to do so.

A final interesting observation is that some are finding it more attractive to operate some of their normal datacenter operations inside the electric grid itself instead of in traditional datacenter buildings. Almost half of the expense of operating a datacenter is in the cost of electricity, not so much in the cost of the computers that operate in them! Some find that it cuts the costs in half and also greatly increases the availability of their datacenter operations to embed their computing into the grid. Salt River Project in Phoenix is leading in this direction.

Our constellation of modular datacenters is built right into the power grid in your community, and all over the world.

- The most expensive part of cloud services happens to be the electric power to run them.
- Putting the datacenter into your own community allows you to provide secure, low latency service.
- This approach is more reliable than any datacenter housed in a building.
- This will become the largest computing complex in the world.



"In the foreseeable future, datacenters will consume 8% of all power generated in the U.S."
- Clinton Poole, SRP

It is estimated that 2% of all electric power generated in the United States today goes to powering datacenters. By the end of a decade, the estimate is that some 8% of all power generated in the United States will be used to power datacenters. Some estimates are that datacenters will eventually consume some 22% of all electric power. It is no wonder that there is such interest in pursuing this modern approach to computing.

A Concluding Thought

There is really no reason why the economies and resiliency of the Agile Fractal Grid could not be used across the entire state of Rhode Island given the current direction and intensions of the Power Sector Transformation. Although invented to serve the needs of rural America through intelligent resourcefulness, we might be mindful of the question recently raised to us by the CEO of Duke Energy: "Our technical people have pointed out to us that at the physics level there is really no difference to the way that electricity works in rural environments than it does in a city environment. So, let me ask the question again. Is there any valid reason why you have excluded us from these conversations?" We were of course happy to bow to the wisdom of her question.

Perhaps this approach would be useful to Rhode Island, too.