AN IMPROVED CHANNEL AWARE SMART GRID TRANSMISSION FOR MANET

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Abstract: A modern power grid needs to become smarter in order to provide an affordable, reliable, and sustainable supply of electricity where The channel average non fading duration and average fading duration is utilized as a measure of link stability, combined with the traditional hop-count measure for path selection. The protocol then uses the same information to predict signal fading and incorporates path handover to avoid unnecessary overhead from a new path discovery process. This protocol provides a dual-attack for avoiding unnecessary route discoveries, predicting path failure leading to handoff and then bringing paths back into play when they are again available, rather than simply discarding them Each smart transmission grid is regarded as an integrated system that functionally consists of smart components, smart control centers, and smart transmission networks And it can evaluate and simulated through NS2 simulation.

1. INTRODUCTION

Growing populations and industrializing countries create huge needs for electrical energy. Unfortunately, electricity is not always used in the same place that it is produced, meaning long-distance transmission lines and distribution systems are necessary. But transmitting electricity over distance and via networks involves energy loss. So, with growing demand comes the need to minimize this loss to achieve two main goals: reduce resource consumption while delivering more power to users. Reducing consumption can be done in at least two change consumer habits.

The Electric power transmission grid has been progressively developed for over a century [1], from the initial design of local dc networks in low- voltage levels to three phase high voltage ac networks, and finally to modern bulk interconnected networks with various voltage levels and multiple complex electrical components. The development of human society and economic needs was the catalyst that drove the revolution of transmission grids stage- by-stage with the aid of innovative technologies. As the backbone used to deliver electricity from points of generation to the consumers, the transmission grid revolution needs to recognize and deal with more diversified challenges than ever before. It should be noted that in this paper the word ―grid‖ refers not only to the physical network but also to the controls and devices supporting the function of the physical network, such that this work is aligned with the ongoing smart grid initiative. In this paper, we summarize the challenges and needs for future smart transmission grids into four aspects.

1.1 Environmental challenges

Traditional electric power production, as the largest man-created emission source, must be changed to mitigate the climate change [2]. Also, a shortage of fossil energy resources has been foreseen in the next few decades. Natural catastrophes, such as hurricanes, earthquakes, and tornados can destroy the transmission grids easily. Finally, the available and suitable space for the future expansion of transmission grids has decreased dramatically.

1.2 Market/customer needs

Full-fledged system operation technologies and power market policies need to be developed to sustain the transparency and liberty of the competitive market. Customer satisfaction with electricity consumption should be improved by providing high quality/price ratio electricity and customers' freedom to interact with the grid.

1.3 Infrastructure challenges

The existing infrastructure for electricity transmission has quickly aging components and insufficient investments for improvements. With the pressure of the increasing load demands, the network congestion is becoming worse. The fast online analysis tools, wide-area monitoring, measurement and control, and fast and accurate protections are needed to improve the reliability of the networks.

1.4 Innovative technologies

On one hand, the innovative technologies, including new materials, advanced power electronics, and communication technologies, are not yet mature or commercially available for the revolution of transmission grids; on the other hand, the existing grids lack enough compatibility to accommodate the implementation of spear-point technologies in the practical networks.

Whereas the innovation of the transmission grid was driven by technology in the past, the current power industry is being modernized and tends to deal with the challenges more proactively by using state-of-the-art technological advances in the areas of sensing, communications, control, computing, and information technology [3]–[7]. The shift in the development of transmission grids to be more intelligent has been summarized as ―smart grid,‖ as well as several other terminologies such as IntelliGrid, GridWise, FutureGrid, etc.

Utilities are increasingly deploying advanced monitoring, communications,
computing and information technologies to support such **―smart grid‖** applications such as wide area monitoring and control, integration of bulk or distributed renewable generation, distribution automation and demand response. Companies face significant challenges when deploying these technologies, including:

- Selecting technologies that best meet current and future business needs and regulatory requirements while minimizing the risk of early obsolescence and vendor lock-in.
- creating an overall architecture that integrates the many intelligent devices, communications networks and enterprise systems to utilize resources and provide information to all users
- Managing the tremendous amount of data that is generated by the smart grid to convert data into actionable information and effectively present the information to the people who need to take action.
- Managing a growing network of intelligent devices that have different capabilities and that use different protocols and data formats in a way that optimizes performance.

- Ensuring that the workforce has the skills necessary to design, operate and maintain equipment and systems that use new technologies.

The IntelliGrid Program will address these challenges by:

- Tracking federal government and regulatory activities relating to standards, cyber security and communications, and interpret the impact that these actions will have on the utility industry.
- Promoting interoperable systems by contributing to the development of key smart grid standards, assessing emerging standards, conducting interoperability tests of products that implement key standards and providing information to utilities on how to implement standards.
- Defining requirements for utility communications networks and assesses key communications technologies
- Facilitating smart grid demonstration projects around the world to better understand and advance the use of distributed energy resources in smart grids.

2. FRAMEWORK AND CHARACTERISTICS OF SMART TRANSMISSION GRIDS

The metrics identified above are used in Section 3 to describe deployment status as organized around six major characteristics of a smart grid. These characteristics are derived from the seven characteristic in the Modern Grid Strategy work described earlier and augmented slightly in the organization of the metrics workshop. The sixth characteristic in the table is a merger of the workshop characteristics a) Addresses and Responds to System Disturbances in a Self-Healing Manner and b) Operates Resiliently Against Physical and Cyber Attacks and Natural Disasters. The same metrics substantially contribute to both of these concerns.

2.1 Enables Informed Participation by Customers

Consumers become an integral part of the electric power system. They help balance supply and demand and ensure reliability by modifying the way they use and purchase electricity. These modifications come as a result of consumers having choices that motivate different purchasing patterns and behavior. These choices involve new technologies, new information about their electricity use, and new forms of electricity pricing and incentives.

2.2 Accommodates All Generation and Storage Options

Consumers become an integral part of the electric power system. They help balance supply and demand and ensure reliability by modifying the way they use and purchase electricity. These modifications come as a result of consumers having choices that motivate different purchasing patterns and behavior. These choices involve new technologies, new information about their electricity use, and new forms of electricity pricing and incentives.

2.3 Enables New Products, Services, and Markets

Correctly-designed and -operated markets efficiently reveal cost-benefit tradeoffs to consumers by creating an opportunity for competing services to bid. A smart grid accounts for all of the fundamental dynamics of the value/ cost relationship. Some of the independent grid variables that must be explicitly managed are energy, capacity, location, time, rate of change, and quality. Markets can play a major role in the management of these variables. Regulators, owners/operators, and consumers need the flexibility to modify the rules of business to suit operating and market conditions.

To achieve the aforementioned smart features and characteristics, the enabling technologies include the following.

New materials and alternative clean energy resources. The application of new materials and devices in power systems will improve the efficiency of power supply by increasing power transfer capabilities, reducing energy losses, and lowering construction costs. The high penetration of alternative clean energy resources will mitigate the conflicts between the human society development and environment sustainability.

Advanced power electronics and devices, advanced power electronics will be able to greatly improve the quality of power supply and flexibility of power flow control.

Sensing and measurement, smart sensing and Measurement and advanced instrumentation technologies will serve as the basis for communications, computing, control, and intelligence.

- Communications. Adaptive communication networks will allow open-standardized communication protocols to operate on a unique platform. Real-time control based on a fast and accurate information exchange in different platforms will improve the system resilience by the enhancement of system reliability and security, and optimization of the transmission asset utilization.
- Advanced computing and control methodologies.

- High-performance computing, parallel, and distributed computing technologies will enable real-time modeling and simulation of complex power systems. The accuracy of the situation awareness will be improved for further suitable operations and control strategies. Advanced control methodologies and novel distributed control paradigms will be needed to automate the entire customer-centric power delivery network.
- Mature power market regulation and policies. The mature regulation and policies should improve the transparency, liberty, and competition of the power market. High customer interaction with the electricity consumption should be enabled and encouraged.

3. SMART GRID CONCEPTUAL MODEL

The NIST Smart Grid Conceptual Model helps stakeholders understand the building blocks of an end-to-end smart grid system, from Generation to (and from) Customers, and explores the interrelation between these smart grid segments.

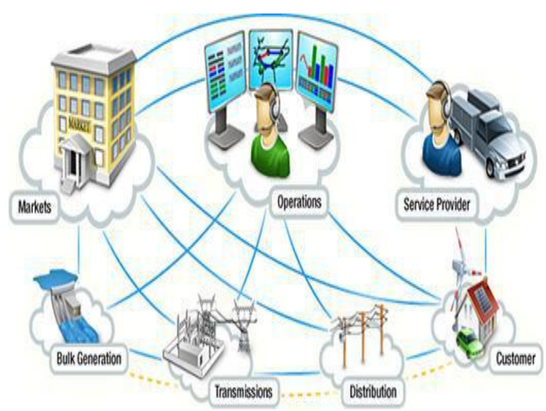

Figure 1: Smart Grid Conceptual Model

Smart Grid Conceptual Model provides a high-level framework for the smart grid that defines seven important domains: Bulk Generation, Transmission, Distribution, Customers, Operations, Markets and Service Providers. It shows all the communications and energy/electricity flows connecting each domain and how they are interrelated. Each individual domain is itself comprised of important smart grid elements that are connected to each other through two-way communications and energy/electricity paths. These connections are the basis of the future, intelligent and dynamic power electricity grid.

- **Bulk Generation**

The Bulk Generation domain of the smart grid generates electricity from renewable and non-renewable energy sources in bulk quantities. These sources can also be classified as renewable, variable sources, such as solar and wind; renewable, non-variable, such as hydro, biomass, geothermal and pump storage; or non-renewable, non-variable, such as nuclear, coal and gas. Energy that is stored for later distribution may also be included in this domain.

- **Distribution**

The Distribution domain distributes the electricity to and from the end customers in the smart grid. The distribution network connects the smart meters and all intelligent field devices, managing and controlling them through a two-way wireless or wireline communications network. It may also connect to energy storage facilities and alternative distributed energy resources at the distribution level.

- **Customer**

The Customer domain of the smart grid is where the end-users of electricity (home, commercial/building and industrial) are connected to the electric distribution network through the smart meters. The smart meters control and manage the flow of electricity to and from the customers and provide energy information about energy usage and patterns. Each customer has a discrete domain comprised of electricity premise and two-way communications networks. A customer domain may also generate, store and manage the use of energy, as well as the connectivity with plug-in vehicles.

- **Operations**

The Operations domain manages and controls the electricity flow of all other domains in the smart grid. It uses a two-way communications network to connect to substations, customer premises networks and other intelligent field devices. It provides monitoring, reporting, controlling and supervision status and important process information and decisions. Business intelligence processes gather data from the customer and network, and provide intelligence to support the decision-making.

- **Markets**

The Markets domain operates and coordinates all the participants in electricity markets within the smart grid. It provides the market management, wholesaling, retailing and trading of energy services. The Markets domain interfaces with all other domains and makes sure they are coordinated in a competitive market environment. It also handles energy information clearinghouse operations and information exchange with third-party service providers. For example, roaming billing information for inter-utility plug-in-vehicles falls under this domain.

- **Service Provider**

The Service Provider domain of the smart grid handles all third-party operations among the domains. These might include web portals that provide energy efficiency management services to end-customers, data exchange between the customer and the utilities regarding energy management, and regarding the electricity supplied to homes and buildings. It may also manage other processes for the utilities, such as demand response programs, outage management and field services.

4. CHANNEL-AWARE AOMDV PROTOCOL COMBINED WITH SMART GRID CHANNEL-AWARE AOMDV PROTOCOL

To obtain link-disjoint paths in AOMDV nd can reply to multiple copies of a given RREQ, as long as they arrive via different neighbors. As mentioned in previous section, route discovery in AOMDV results in selection of multiple loop-free, link-disjoint paths between ns and nd, with alternative paths only utilized if the active path becomes unserviceable. One of the main shortcomings of AOMDV is that the only characteristic considered when choosing a path is the number of hops. Path stability is completely ignored. Thus, selected paths tend to have a small number of long hops meaning that nodes are already close to the maximum possible communication distance apart, potentially resulting in frequent link disconnections. Further, channel conditions are idealized with the path-loss/transmission range model, ignoring fading characteristics inherent in all practical wireless communication environments.

In CA-AOMDV [7], this deficiency is addressed in two ways. In the route discovery phase the ANFD is utilized, explained below for each link as a measure of its stability.

The average non-fading duration (ANFD) is affected by both the physical propagation environment (e.g., obstacles such as trees and buildings) and the node velocities. The ANFD, $\bar{\vartheta}$, is the average length of time that the signal envelope spends above a network specific threshold, Rth, and is given by

$$\bar{\vartheta} = \frac{1}{\rho f_T \sqrt{2\pi(1+\mu^2)}} = \frac{c\sqrt{G_0}}{R_{\text{th}} d^{\alpha/2} f_0 \sqrt{2\pi(v_T^2 + v_R^2)}} \quad (3.1)$$

where $\rho = R_{th}/R_{rms}$, ($R_{rms} = \sqrt{G_0 d^{-\alpha}}$) is the ratio between the transmission threshold and the root mean square power of the received signal, $f_T = f_0 v_T / c$ is the maximum Doppler shift of the transmitter, f_0 is the transmitter signal carrier frequency, $c \approx 3 \times 10^8 ms^{-1}$ is the speed of electromagnetic radiation (signal speed), and $\mu = v_R/v_T$ is the ratio of the receiver velocity to that of the transmitter where v_R and v_T are the receiver and transmitter node velocities, respectively.

It can be surmised from (3.1) that the value of the ANFD is high for low transmission threshold (low ρ), and decreases with an increase of μ or ρ. Further, increased node mobility (captured by v_R and v_T)

would cause a corresponding decrease in the ANFD due to the increased rate of signal fluctuations and that an increased link distance (via d) would cause a decrease in ANFD due to a greater path-loss influence.

In MANETs, choice of stable links for route establishment ensures reliable packet transmission. Link stability can be represented by the distance between the nodes forming the link, and their mobilities. Thus, any measure of how stable a link is should include these factors. The ANFD is inversely proportional to link length, d, and node velocities v_T and v_R. The ANFD of a link between two highly mobile or separated nodes will be shorter than that of a link between two slow moving and/or close nodes. In short, a link with a high ANFD will have a relatively long lifetime. Thus, using the ANFD as a metric will result in choosing more stable links. There is minimal extra calculation required to determine ANFD. The parameter Rrms can be garnered from received packet signal strengths, and f_T can be calculated via $f_T = f_0 v_T / c$. Thus, to calculate $\bar{\vartheta}$, nodes simply need to include speed and location in the header of each packet. In the route maintenance phase, instead of waiting for the active path to fail, we pre-empt a failure by using channel prediction on path links, allowing a handover to one of the remaining selected paths. This results in saved packets and consequently smaller delays.

4.1 Route Discovery in CA-AOMDV

Route discovery in CA-AOMDV is an enhanced version of route discovery in AOMDV, incorporating channel properties for choosing more reliable paths. In the previous, the ANFD is defined for one link of a path, according to the mobile-to-mobile channel model. CAAOMDV uses the ANFD as a measure of link lifetime. The duration, D, of a path is defined as the minimum ANFD over all of its links,

$$\mathcal{D} \triangleq \min_{1 \le h \le \mathcal{H}} \text{ANFD}_h, \quad (3.2)$$

where h is link number, and H is number of links/hops in the path. Before forwarding a RREQ to its neighbors, a node inserts its current speed into the RREQ header so that its neighbors can calculate the link ANFD using (3.1). The path duration, D, is also recorded in the RREQ, updated, as necessary, at each intermediate node. Thus, all information required for calculating the ANFD is available via the RREQs, minimizing added complexity. Similarly to the way the longest hop path is advertised for each node in AOMDV to allow for the worst case at each node, in CA-AOMDV the minimum D over all paths between a given node, ni, and nd, is used as part of the cost function in path selection. That is,

$$\mathcal{D}_{\min}^{i,d} \triangleq \min_{\zeta \in \text{path\_list}_i^d} \mathcal{D}_\zeta \quad (3.3)$$

where path_list di is the list of all saved paths between nodes ni and nd. The route discovery update algorithm in CA-AOMDV is a slight modification of that of AOMDV. If a RREQ or RREP for nd at ni, from a neighbor node, nj , has a higher destination sequence number or shorter hop-count than the existing route for nd at ni, the route update criterion in CA-AOMDV is the same as that in AOMDV.

Table 1: Comparison of routing table entry structures in AOMDV and CA-AOMDV

AOMDV routing table	CA-AOMDV routing table
destination IP address	destination IP address
destination sequence number	destination sequence number
advertised hop-count	advertised hop-count
path list {(next hop IP 1,hop-count 1), (next hop IP 2,hop-count 2),$\cdots$}	$\mathcal{D}_{\min}$
	path list {(next hop 1,hop-count 1,$\mathcal{D}_1$), (next hop 2,hop-count 2,$\mathcal{D}_2$),$\cdots$}
expiration timeout	expiration timeout
	handoff dormant time

However, if the RREQ or RREP has a destination sequence number and hop-count equal to the existing route at ni but with a greater Di, dmin, the list of paths to nd in ni's routing table is updated. So, in CA-AOMDV, path selection is based on Di, dmin as well as destination sequence number and advertised hop count. The routing table structures for each path entry in AOMDV and CA-AOMDV are shown in Table 3.1. The handoff dormant time field in the routing table for CAAOMDV is the amount of time for which the path should be made dormant due to channel fading. It is set to the maximum value of the AFDs over all links in the path. This use of handoff dormant time is described in more detail in the next section.

4.2 Route Maintenance in CA-AOMDV

In mobile environments, it is necessary to find efficient ways of addressing path failure. Using prediction and handoff to pre empt fading on a link on the active path, disconnections can be minimized, reducing transmission latency and packet drop rate. Route maintenance in CA-AOMDV takes advantage of a handoff strategy using signal strength prediction, to counter channel fading. When the predicted link signal strength level falls below a network-specific threshold, the algorithm swaps to a good-quality link. The fading threshold is chosen so as to provide robustness to prediction errors. The presence of multiple users experiencing independent channel fading means that MANETs can take advantage of channel diversity, unlike data rate adaptation mechanisms such as Sample Rate. All nodes maintain a table of past signal strengths, recording for each received packet, previous hop, signal power and arrival time. Ideally there will be M packets where M is the required number of past samples from M being the number of previously received values used to predict, at discrete time interval n with a discrete time step of t, the signal strength ψ time intervals into the future. Then, if ˆx(n+ψ) is the LMMSE prediction for the received signal strength, x(n + ψ), at discrete time
n + ψ, we have

$$\hat{x}(n+\psi) = \mathbf{R}_{\hat{x}x}^T \mathbf{R}_{xx}^{-1} \mathbf{x} \quad (3.4)$$

However, this will depend on the packet receipt times compared with the specified discrete time interval, t. If packets are received at time intervals greater than t, sample signal strengths for the missed time intervals can be approximated by the signal strength of the packet closest in time to the one missed. If packets are received at intervals of shorter duration than t, some may be skipped. An example of handoff in CA-AOMDV is shown in Fig. 3.1. The handoff process is implemented via a handoff request (HREQ) packet. The CA-AOMDV handoff scheme is described below.

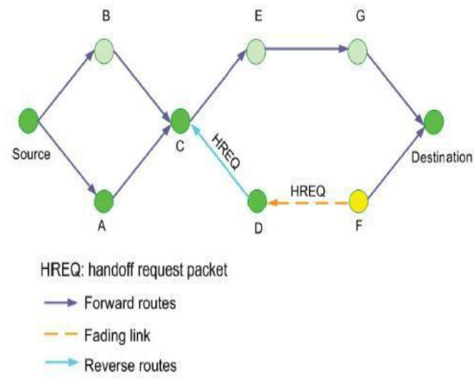

Figure 2: Handoff in CA-AOMDV PredictionLength

The LMMSE prediction algorithm performs quite poorly if not matched to the current channel conditions. Therefore, the prediction length should not be too long. In CA-AOMDV a given node may have multiple paths to the destination, each with a different next hop node. If an intermediate node has multiple paths to the destination, upon receiving an HREQ it can immediately switch from the active path to a good alternative one, without further propagating the HREQ. Therefore, the time needed to implement a handoff in CA-AOMDV is the duration, in terms of the discrete time interval t, for the HREQ to be propagated to the fading link uplink node. For example, if ni and nj are neighbors in a given path and nj predicts a fade on link li,j , it will generate a HREQ and forward it to ni. Thus, a suitable prediction length

ψ in (3.4) corresponds to the number of discrete time

intervals, t, for transmission of a HREQ between nj and ni, which can be approximated by using the data propagation time Tij from nj to ni, with

$$\psi = \text{round}(T_j^i / \Delta t). \quad (3.5)$$

where ―round‖ is the integer rounding function. In addition to choosing a threshold with a suitable error margin, as described above, to enhance the robustness of the prediction process to errors in CA-AOMDV the signal strength is predicted at t0 + ψ and t0 + 2ψ. The algorithm is detailed in the next section.

5. PERFORMANCE METRICS

- **Throughput**

Throughput is the number of useful bits per unit of time forwarded by the network from a certain source to a certain destination, excluding protocol overhead, and excluding retransmitted data packets. Throughput is the amount of digital data per time unit that is delivered over a physical or logical link, or that is passing through a certain network node

Throughput = (total_packets_received) / (simulation_time)

- **Delay**

It is defined as the average time taken by the packet to reach the server node from the client node. Delay = (total_packets_sent) / (simulation_time)

- **Delivery Ratio**

Packet Delivery Ratio is defined as the average of the ratio of the number of packets received by the receiver over the number of packets sent by the source.

Delivery Ratio = (total_packets_receeived) / (total_packets_sent)

- **Dropped packets**

It is number of packets dropped due to the effect of link breaks. The dropped packets may be a control packets or data packets.

6. CONCLUTION

This paper has presented a unique vision of the next-generation smart transmission grids. It aims to promote technology innovation to achieve an affordable, reliable, and sustainable delivery of electricity. With a common digitalized platform, the smart transmission grids will enable increased flexibility in control, operation, and expansion; allow for embedded intelligence, essentially foster the resilience and sustainability of the grids; and eventually benefit the customers with lower costs, improved services, and increased convenience. This paper presents the major features and functions of the smart transmission grids in detail through three interactive, smart components: smart control centers, smart transmission networks, and smart substations. Since this initial work cannot address everything within the proposed framework and vision, more research and development efforts are needed to fully implement the proposed framework through a joint effort of various entities.

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