



Lemko Corporation White Paper

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SwarmNet™ - A Moving Self-Organizing Network (SON)

The mobility component of FirstNet

About Lemko Corporation
LEMKO is a privately held corporation headquartered in Itasca, Illinois. The company is the leading provider of DiMoWiNe™ (Distributed Mobile Wireless Network) solutions that change the way mobile wireless networks are deployed and operated. Lemko provides 2G, 3G and 4G LTE cellular systems powered by a virtualized core network. The company's market leading solutions are deployed with carriers, government and military private network operators.

Executive Summary

*Given that traditional commercial 4G networks¹ will comprise the fixed-tower portion of FirstNet, there remains a **capability shortfall** of delivering on-the-move mobile broadband to augment the fixed network, and provide coverage when the fixed FirstNet network is either **overwhelmed, destroyed or non-existent** in a specific area of operation.²*

***SwarmNetworking™**, the ability to dynamically build self-organizing mobile broadband networks, overcomes this capabilities cap. The SwarmNetworking™ application has undergone more than seven years of development and testing and is available today and currently used by military, paramilitary and first responder units.*

Utility to the Department of Homeland Security

The operational challenges of adopting commercial cellular network infrastructure to

¹ With the sale of Motorola's cellular infrastructure division to Nokia-Siemens the US is left without a major cellular network equipment manufacturer.

² Traditional 4G network equipment is of course incapable of meeting SWaP (size, weight and power) requirements for mobility and deploy ability.

the needs of first responders and law enforcement are well understood.³ A traditional 4G network may be FirstNet's most feasible option in densely populated urban areas where network usage demands tend to be more predictable.⁴ However, the traditional network becomes tactically, technically, and economically impractical in rural/remote/in-building operations, if the fixed network is damaged, or in situations when demand surges overwhelm the existing network. Law enforcement and first responders need the capability to build bandwidth capacity on demand. The prerequisite is BYOB – bring your own bandwidth.

The SwarmNet™ application can dynamically build a self-organizing mobile broadband network on the move or at a halt. It consists of two elements - the ODC™ and the Node2™. The network's main building block is the ODC™. It is a complete standalone 4G cellular solution "in a box" with a rich set of features. The mil-spec ODC™ is a world-leading product which meets SWaP (size, weight and power) requirements. It is available in a variety of form factors such as a battery operated wearable form, like a backpack, a UAV mountable design, and a vehicle-installed configuration. ODCs™ have also been deployed on fixed towers using a variety of power sources such as solar, generator, and commercial power. The multi-band ODC™ has an integrated channel scanner feature that identifies available channels, thus ensuring mission flexibility while avoiding operational

³ Chief among the major operational issues of using traditional 4G networking equipment is 4G's Hierarchical networking architecture which challenges planners with multiple single points of failure, large backhaul requirements, enormous signaling overhead, lack of redundancy and design rigidity. Hierarchical networks do not support ad-hoc networking.

⁴ Traditional 4G cellular has limited flexibility to handle capacity surge demands.

denial due to spectrum conflicts. The network administrator can assign bandwidth priorities and feature access rights to subscribers as well as create and manage white/black lists. The ODC™ can integrate seamlessly with an IP-PBX extending the IP-PBX features to the mobile subscriber. ODC™ easily integrates with TETRA and P25 networks through appliances like IPIX. ODCs™ are available in both LTE standards - TDD and FDD and are also offered in CDMA1x, EVDO, GSM-GPRS, and HSPA+ waveforms.

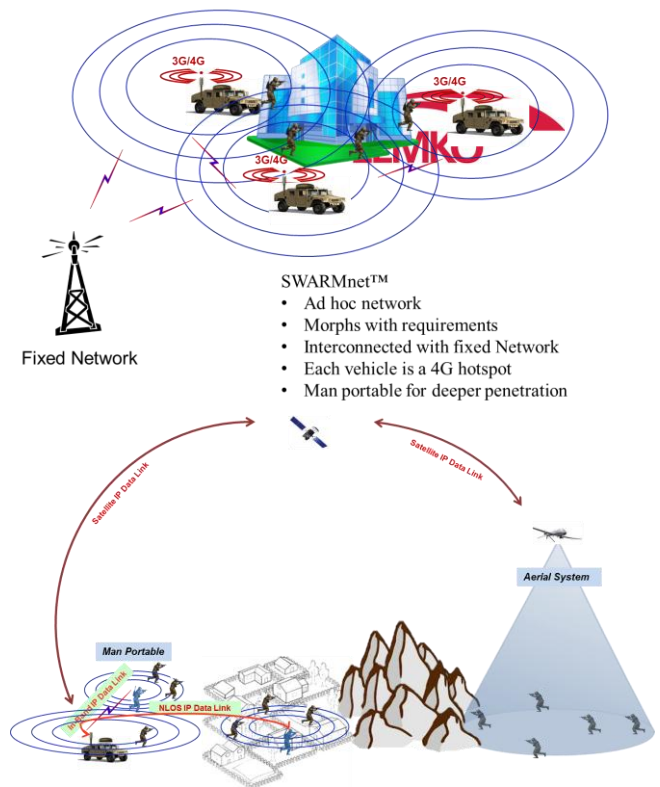
Two or more ODCs™ can swarm together to form a larger broadband coverage area. When swarming, neighbouring ODCs™ self-organize, i.e. they automatically identify and authenticate each other. They coordinate channel availability and synchronize subscriber lists and rules. The number of ODCs™ that can swarm together has no theoretical limit.⁵ The application supports on the move swarming and proves the capability to build a rolling canopy of mobile broadband coverage for convoy missions. SwarmNet™ is designed to dynamically grow or contract with mission requirements. The application supports handoffs between ODCs™ and can be configured to handoff to commercial networks.

A SwarmNet™ is created via IP connectivity between neighbouring ODCs™. The application is highly flexible and supports mesh, star, daisy chain, and hybrid topologies. Should an ODC™ lose its networking IP link, it will continue to operate in stand-alone mode until that link is re-established. Furthermore, the neighbouring ODCs™ will increase RF power to compensate for the coverage gap caused by the lost ODC™. SwarmNet™ is self-organizing and self-healing.

⁵ In the field, more than 100 ODCs™ have been deployed into single SwarmNet.™

SwarmNet™ is a flat IP architecture, which allows traffic to be routed directly to its intended recipient. The flat architecture avoids the necessity of triangulated data paths that are typical in a centralized 4G network. This design radically reduces backhaul requirements making it possible to use high bandwidth applications and to exchange information amongst SwarmNet™ users. It is the only approach that allows for satellite interconnection to be incorporated into a 4G tactical network.⁶

The Node2™ is the SwarmNet™ gateway element to commercial cellular networks. Node2™ supports SS7, MAPP and IS41. It has undergone interoperability roaming testing with over 150 commercial carriers. Node2™ provides the capability to seamlessly roam with commercial cellular allowing SwarmNet™ users uninterrupted service and the convenience of using the same devices and applications on both networks. Likewise, the Node2™ will service as the gateway to FirstNet. To ensure 99.999% reliability of service the Node2™ can be deployed as a multi-site redundant element.



[SwarmNet™ tactical self-organizing networking with the capabilities to seamlessly integrate to the existing fixed network provides the ability to dynamically scale the broadband to meet mission requirements. It gives FirstNet Continuity of Operational assurance should the fixed network be damaged.]

Technical Approach

Description: SwarmNet™ is the tactical adaptation of the Distributed Mobile Wireless Network architecture, or DiMoWiNe⁷. The solution leverages substantial technology breakthroughs in core network vitalization which makes it possible to deliver broadband anywhere from small, lightweight, battery-powered nodes. In addition, this solution takes advantage of exciting innovation in distributed database management that has enabled swarming, seamless interoperability with legacy commercial cellular and interconnectivity with public safety land mobile networks.

SwarmNet's™ ODCs™ run on a virtualized core. Virtualizing and distributing the EPC,

⁶ Lemko Corp. "ARINC and Lemko Demonstrate Seamless 4G LTE Transmission via Satellite Connection." July 11, 2012. ARINC Inc. <http://www.lemko.com/LEMKO_PR/2012.07.11_ARINC_and_Lemko.html>
Lemko Corp. "Hughes and Lemko Corporation Demonstrate High-Speed Wireless 4G/LTE Video Calls over Satellite Backhaul." June 28, 2012. Hughes Network Systems. <http://www.lemko.com/LEMKO_PR/2012.06.28_Hughes.html>

⁷ For more on DiMoWiNe see Fabio Guist, Antonio de la Oliva and Carlos J. Bernardos, "Flat Access and Mobility Architecture: an IPv6 Distributed Client Mobility Management Solution," Institute IMDEA Networks.



IMS and HSS functions transforms a traditional cellular network from a hierarchical-centralized architecture to a **flat IT architecture**. There is no core and hence no requirement to build expensive Layer 3 tunnels to get to the core. By using a virtualized core the cellular session is authenticated, switched, routed, and rated at the ODC then connected to the tactical Cloud as a Layer 7 application. This establishes the shortest path between an end-user and the tactical Cloud.

The benefits of core virtualization are game changing. Virtualization drives SWaP specification and enables a vast array of deployment possibilities providing tremendous operational flexibility. A virtual core network is the most efficient way to deliver data. From an economic standpoint, it can deliver a Gigabyte of data for about one dollar, which is around four dollars less than a traditional 4G solution. Network latency is greatly reduced and signalling overhead is lowered; a majority of data traffic is off-loaded; and routing is optimized and simplified. This approach is backward compatible with 2G and 3G cellular and integrates seamlessly with legacy networks.

The distributed mobile IT network disposes of a centralized mobility anchor point. Instead, it employs a dynamic anchor point that moves with the mobile unit across the network from ODC™ to ODC™. The dynamic anchoring capability enables ODCs™ to form ad hoc mesh networks while on the move, i.e. **swarm**. There is no backhaul since all traffic that is generated and terminated on the same ODC™ stays on that ODC™ with no need to go onto the network. Moreover, traffic between ODCs™ is routed via the most direct or the most operationally practical pathway. There is no triangulation or tramponning of data/call flows. This capability makes this solution

uniquely suitable for satellite networking deployments and novel solution for FirstNet.

Additionally, the architecture's inherent redundant design prevents catastrophic network outages giving it a considerably higher survivability and reliability rates over a traditional cellular network that is riddled with vulnerable single-points of failure elements. Even if an ODC™ temporarily loses its IP connection, traffic on that site will not be interrupted and will still be properly authenticated, metered and rated. Lastly, it is a driven software solution that runs on an inexpensive off-the shelf single host Linux computing platform. Accordingly, it has a very small footprint with minimal power requirements thus facilitating tactical aerial, man transportable mission requirements or small-cell deployments. Virtualization drives SWaP specification and enables a vast array of deployment possibilities providing tremendous operational flexibility.

It's important to note that the world is moving toward a DiWoWiNe design. 3GPP, the cellular industry's standards body, and IEEE, the IT industry's standards body, are addressing the implementation of mobile broadband and are both proposing virtual core networking designs. FirstNet can take advantage of this innovation today.

Commercialization Capabilities SwarmNet™ is the tactical implementation of DiMoWiNe™ which is used in the Lemko's commercial cellular networks around the world. To date, hundreds of ODCs™ and Node1s™, the ODC's™ commercial equivalent, have been sold world-wide.



Hurricane Katrina

Lemko's ODC solution was deployed as part of the Hurricane Katrina relief mission under the QuickLink brand. The relief effort demonstrated the solutions viability to quickly re-establish communications in a disaster stricken area under extremely harsh conditions. Lemko's solution was deployed at the New Orleans Airport and the Naval Support Activity Center. The systems were used by the 82nd Airborne, TSA, US Navy, FEMA, N.O. Airport Authority, New Orleans Police and other public safety groups.



China Earthquake

About 100 ODCs™ swarmed to re-establish communications in the aftermath of the 2008 earthquake in the Sichuan province. SwarmNet™ provided on-demand C3 capability to first responders while the commercial carriers struggled to repair the 3,000 damaged communication towers.



X-4

The X-4 ODC™ is the world's smallest man-portable battery operated 4G solution. The X4 supports in-band and WiFi backhaul. It is ideal for covert operations, search and rescue missions, providing coverage in-buildings, and remote dismounted operations.

Classification and Control

SwarmNet™ and the ODC™ are Lemko trademarks and are protected by the following US patents; 7,539,158; 7,486,967; 7,548,763; 7,856,233; 7,653,414; 8,224,322; 8,046,420; 8,107,409; 8,089,920; 8,036,158; 7,840,230; 8.107,409; and 8,224,322. Other patents pending.

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