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Customer-in-Loop Adaptive Supply Chain Migration Model to Enable IoT

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Abstract*: Poised to smart citizenry engagement, an unprecedented deluge of high quality streaming services induce a major data traffic challenge in Fourth Generation (4G) bandwidth and coverage, the upcoming smart city expectations cannot be ignored, eventually. The bottlenecks in ever exploiting benefits such as e-Life, to name a few at Mobile Equipment Providers (MEP) tiers, are complemented at Device Dependent Device Independent (D3I) configurations inherent at various tiers of Mobile Service Providers (MSP). While enabling a Supply Chain Management (SCM) augments a unique system support involving the MSPs and MEPs for desired Customer Relationship Management (CRM), Ad hoc Resource Planning (ARP), which we found prevalent in migration scenario from 4G to 5G technology deployment. Despite its complexity both in term of one-to-many and many-to-one across diverse MSP and MEP options, SCM operational objectives sets forth a unique challenge, hence is the main objective for our work presented here. In this paper, we presented a framework to enhance the 4G legacy in mobile service provider capacity for smart city Machine-to-Machine (M2M) backbone. The migration process is assessed with proposed strategic, technical and operational indicators, which demonstrate its adaptability and flexibility while integrating in conventional 4G deployments, especially taking into account radio devices and applications.

Web-enabled Software Define Radio devices and applications are used to index the migration cost and support SCM planning and execution. We identify, the decentralization of mobile service providers infrastructure plays a major role in reducing the embedded complexity which often appears as primary bottleneck. MSP as a key player in the elasticity of migration, we presented a platform to support large as well as low MEP-MSP co-deployments. Pareto multi-criteria optimization is used to find the strategic indicators which are primary Transformation Steering Factors (TSF), valid in both device dependent or device independent M2M migration. We expose our result for achieving TSF, while rolling interoperability and reconfiguration of device deployed in a typical volatile inter-MSP or intra-MSPs tiers. Pareto Migration Indicators (MI) are optimized successively progressing across the transformation schemes; relative to base-line MSP services, hence enabling a lucrative choice while elasticity of provider-centric cost depends adaptively on technology legacy and M2M access of User Equipment (UE).

***Keywords*: Supply Chain Management (SCM), IP Networks, IoT, Adaptive Optimization, Smart City.**

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I. INTRODUCTION

Networks laying foundation on 5th Generation, enabling Inter of Things (IoT) have to cater stringent new demands imposed by ever-growing rate of global subscriber figured out potential of one billion new customers subscriber spurred in a pseudo digital global population era.

The capacity of available channel plays a key role since the growth of digital data traffic whether a wired or wireless medium is taken as into consideration [1, 2].

Engaging new M2M or UE while maintaining connectivity at any cellular node, broadly speaking of one typical mobile tower induce second order challenge in migrating 4th generation network towards tremendous increase in data traffic for 5th generation cellular services [3, 4, 5].

It is imperative at the mobile operator's viewpoint to estimate fixed marginal cost [4, 6], meanwhile maintaining reduction in operational cost of network to a significant level. Improvement of SE and associated area capacity coverage over the viewpoint of technical and practical roadmap needed to ensure aforementioned challenges [7, 8, 9].

For paving the way towards the 5th Generation (5G) Telecom onto legacy needs evolutionary and revolutionary mobile system design, yet taking into account reduction in up-gradation migration cost. User equipment seamlessly churn the underlying 5G mobility architecture benefits [7, 10, 11, 12].

The mobility (or roaming) of UE while handing over between two cellular host antennas (or nodes) should remain seamless, generally known as soft handover to another MSP [13, 14].

Each imaginable technological growth is a precursor to scalability of deployment as well as extended scope of up-gradation. The mobile operators role the dynamics of core laid either at providers of mobile equipment or service provision onto mobility [5, 15].

Capabilities of mobile operators brought together in a powerful mix of timeshared physical infrastructure [16], human resource and expert knowledge across the globe to compete IT and multimedia-hands on function at UE irrespective of skill or merely novice [16, 17].

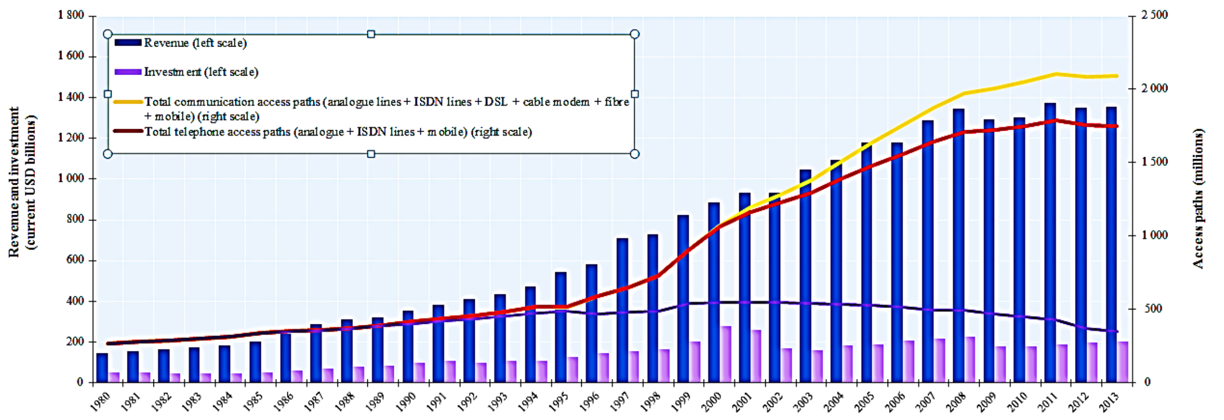

Figure 1 Migration KVPI per Annual Elasticity of Cost Benefit for Multimedia data traffic across cellular generations since 2nd Generation onwards. [27]

The legacy of 4th generation (4G) skills lacks deftness and diversified abilities to be performed with various tiers of components, coordinated vigilantly with transparent integration—a manifest towards M2M resourcefulness and pluggable extended technologies [18, 19, 20, 21]. The inter-MSP networks at M2M tier needs soft management, steep learning curve attributing mindful knowledge at mobile service provider edge. The mobile service provider complement the joint behavior of mobile equipment provider to realize always available, always online. In addition to sum of 4th generation legacy tiers, it enables management of logistic, warehouse and operations unified scalability, yet approving wider service range in totality [19, 21, 22, 23]. Despite the acknowledgement to all mobile service provider aspiration, an air-time sharing review should be respected by all operational managements at all mobile service providers in service loop. While Ericson deem M2M out of the band, they indicate alone standard mobile handset or UE required higher data rate, especially devices augmenting tablets, smart phones or per se laptops as large as more than 35 times [24, 25, 26].

Internet communication has escalated to deluge of data traffic in association with aggressively deployed IP based networks known widely as M2M tiers, rising to traffic dynamics non-linearity in comparison to previous eras of steadier data throughput [22, 27, 28]. Cisco revealed IP bandwidth increase above 75 percent to cater video data services, whether online video channels or streaming BluRay services, to name a few. While Qualcomm as System on Chip (SoC) or Network on Chip (NoC) chipset provider, gearing up to M2M end-to-end connectivity, enabling Internet of Things (IoT)—things like clothes, cars, trains etc. [29, 30, 31], yet solutions for mobile service or equipment provider impose migration challenges in transforming primary access path infrastructure at minimal US$ investment and significant revenue. Figure 1, depicts Key Visual Performance Indicators (KVPI) to benchmark amount of text, image, audio and video data traffic for Cisco devices furnishing Qualcomm multimedia SoC tailoring almost double capacity in contrast to last decade, leading to above 1000 times bandwidth surge extrapolated to enter in 3rd decade of 21st century i.e., a Smart City Smart Ecosphere (SCSE) [27, 32, 33, 34]. Proliferation of IoT accelerated mobile traffic to provide stable, reliable, A3O © end-to-end connectivity lead to data hungry instantiation—a precursor to advance level of mobile equipment providers and yet maintaining minimum cost overheads at primary tiers of 4th generation, secondary tiers of software programmable radio equipment (hence flexible to scale) and tertiary subscriber services [35, 36, 37, 38]. We shall discuss three layers while presenting elastic cost model in later section.

The unprecedented streaming demand for ultra-high definition videos and gaming entail the low cost smart phones availability to increase the demand for real time response not only on standard mobile functions but low latency data throughput [39, 40], yet performing device care function in the background required to maintain integrity of host operating system as Android, IoS, Blackberry, Symbian, covering a large mobile handset market since the beginning of this decade [5, 41, 42, 43].

The immersion in data centric multimedia functionality is expected to load about 70% a typical 4G (Long Term Evaluation) when it facilitate IP based services readily pluggable into the IoT from the perspective of smart city. It precede the fact the traffic generated on voice over would contribute about 0.4% as compared to its counterpart data traffic towards geographically diversified cloud servers rising band width to as estimated touching 86% network ceil, excluding 6.9 billion individual handsets globally [25, 27, 44, 45]. Tremendously growing gap between the 4th generation and expected data traffic growth demands 5th generation hosted system, though upgraded and serving flexible network at low cost not only in terms of human and infrastructure resources, but subscriber services aligning IoT devices as well [46, 47, 48].

Remaining paper is organized as follows:

We laid foundation of IoT in next section, which provides any electronic device equipped with IP in any capacity or object that can be attached physically to provide real time smart services for e.g., at garments store, personal vehicles or city metros.

Section III covers the contemporary research work leading to inevitable demand for flexible performance indices [25, 49, 50] and seamless migration from a 4th generation networks to gear up and enable IoT functionality.

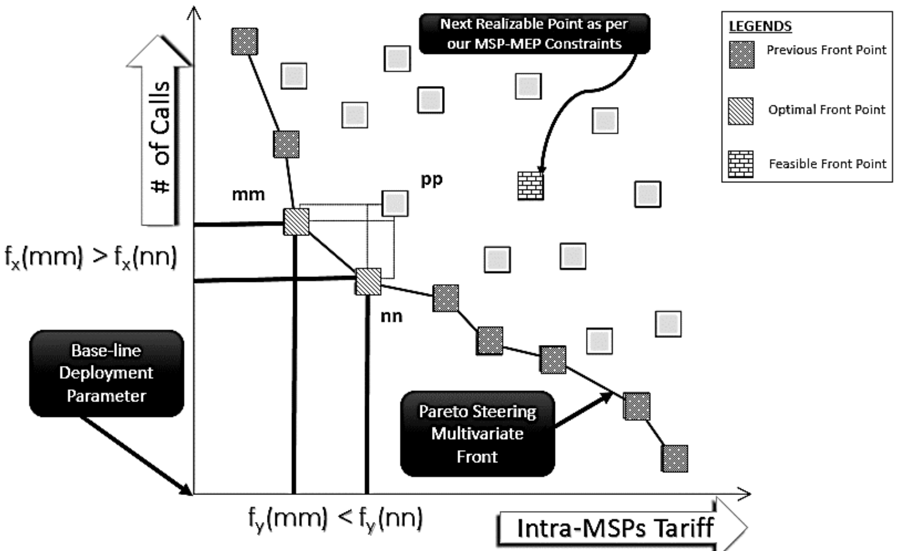

Figure 3.2. Pareto Optimization for bi-objectives (only one pair is shown here from Section III)

We indicated migration parameters, an outcome of Pareto wave front [51, 52, 53, 54] successive transformation to meet customer-centric deployment indices in Section IV.

Migration parameters play elastic role to provide reliable connectivity, hence extend the functionality benefits in 4th generation to be Always Available, Always Connected (A3C) © scenario [18, 21, 22, 24] and are exemplified in Section V.

Finally, we presented the discussion and benefits of our migration model in Section VI which enable the extension of existing infrastructure of 4th generation networks to accommodate IP based functionality—a backbone to any smart city. Future work is also suggested in this section to conform a tailor made scenario i.e., limited Quality of Service (QoS) package in a mobile service provider network [55, 56, 57, 58].

II. MSP-MEP MODEL FOR MIGRATION

A. Foundation of Vectored Migration Space

We aim to build a migration framework, to cope up trifold migration issues at planning, management and deployment tiers [59].

Firstly, complexity is projectable to any computational or analytical software platform as simple as Microsoft Excel environment [60, 61, 62]. Successive approximation ensure the adherence to 4G deployments, consolidation with essential parameters, yet reaching to a desired optimal Pareto solution at 5G onset.

Secondly, gradual improvement is tracked on the Pareto wave front to bound 4G cost function without sacrificing aimed 5G objective function. Unlike [34, 50, 58, 59] elasticity of cost tailoring functional migration to mitigate rebinding 4G average functional cost is obtained reflecting multi-dimensional scattered parameters for MSPs in particular and the client-end devices such as MEPs. into a customer-centric spatial domain, as formulated below.

Our 5G Effective Migration Space Model (5G-EMSM) derivatives assume any giver first order scenarios (as ζ here forth) at pre-operational stage loosely coupled to converge into desired transformation steering parameter, hence maintaining the ultimate flexibility without compromising the robustness and adaptive simplicity in contrast to methodology offered in [59, 60, 61, 62].

B. Modeling Migration Steering Factors

We use Dash-IF Mediabench [9, 25, 57] to mimic multimedia traffic for an application scenario ζ, system is presumed at cellular blocks layers to create a possible linear space of transformation i.e., J. It is represented in parametric quad tuple of $\mathbf{P}_x^{\zeta}$, $\mathbf{P}_y^{\zeta}$, $\mathbf{P}_z^{\zeta}$ and $\mathbf{P}_l^{\zeta}$ defined as follows:

$J((\mathbf{P}_x^{\zeta}, \mathbf{P}_y^{\zeta}, \mathbf{P}_z^{\zeta}), \mathbf{P}_l^{\zeta})$ Equation (1)

Each parameter vector is obtained in following sub-spatial domains:

P_x^{ζ} from the specification of existing MEP to desired 5G inter operate-ability [18, 21, 26],

P_y^{ζ} is defined prior to operational stage on the account acquisition performance profiling, where profiler [18, 21, 27] adheres streaming video media taxing traffic, also shown in prior to operational or on-line generated statistics reflecting true traffic in any scenario as shown in Figure 2.

P_z^{ζ} corresponds to simulated objective function to cater MSP cost elasticity joint with intra mobile service providers transparent migration (as homing or roaming) for UE at the subscribed set of services. Robust cost elasticity is accumulatively counter operational data traffic while serving heavy BluRay video streaming also available in Medibenchmark [9, 63, 64].

P_l^{ζ} represent iterative set of parameters while transformation in progress is mapped to optimize

III. PARETO OPTIMIZATION IN MTE

A. Pareto Successive Optimization for KVPIs

P_x^{ζ}, P_y^{ζ}, P_z^{ζ} in a constant software loop, which retain parametric feedback on Pareto

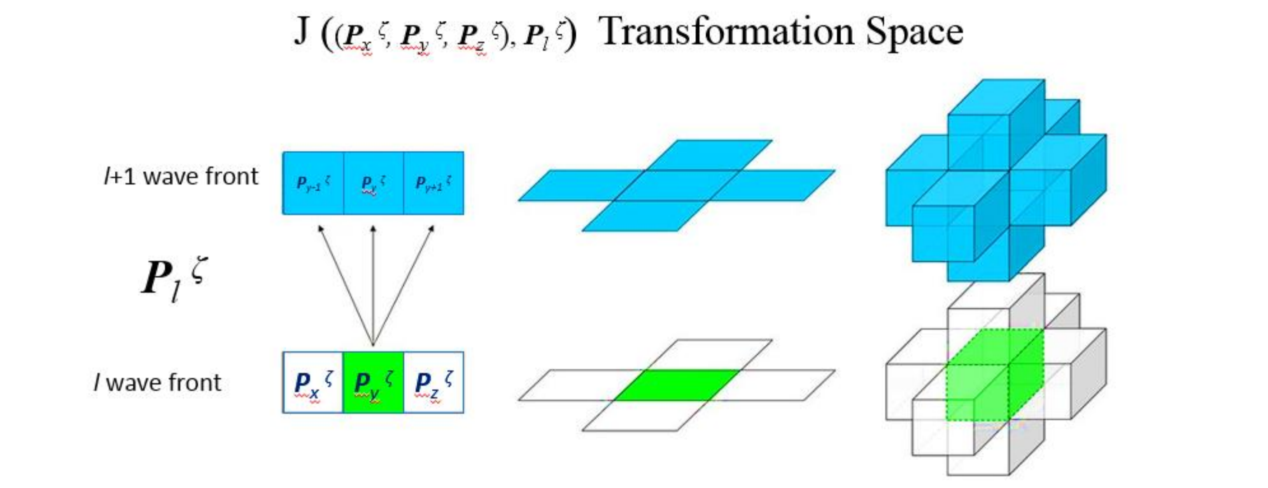

Figure 3. MSP-MEP Cost Elasticity Model and Steering Factors Evolution (See Section II-B)

wave front for analysis in Migration Transformation Engine (MTE). Iteratively, Pareto optimal wave front is evaluated, leading to desired elasticity of migration parameters and hence generate next wave front in Pareto optimization space. Following the transformed vector space **J**, all mobile service provider at each unit of data traffic participate to reach Pareto desired wave front [64, 65, 66]. It may be noted, there may be best optimization solution independent of available resource on the ground, we look for desired objectives to meet equipment constraints, deployment constraints, operational constraints, and flexibility (in terms of 5G scalability). We expect Site Migration Planner (SMP) to provide actual scenario-centric constraints (widely known as client constraints feasibility report [27, 37, 67, 68] in aforementioned domains to the MTE framework (proposed here).

B. Cost Elasticity Constraints in SCM Transformation

For a typical application scenario ζ, the available set of deployment versus operational block M associatively accumulate assessed subscriber load services, client or customer air-time and broadcasted energy either to tower, macro cell, microcell or tithers—typical to mentioned in [69, 70, 71, 72, 73]. Baseline or reference scenario is divided in equipment constraints, deployment constraints, operational constraints, and flexibility constraints. These constraints are estimated in depth as depicted in Figure 3, and shall be discussed in Section IV. Elasticity of cost is also considered relative to the reference deployment can be termed as RDC. Then individual transformed wave front can be expressed as constraint function mentioned below:

$$\alpha_o(\zeta^o) = \sum_{y=1}^{p}\sum_{x=1}^{q}((f_{xy}^o\, g_{xy}^o\;\; M_{xy}^o) + \beta_{xy}^o + \gamma_{xy}^o \qquad \forall\, p,q\; \in \zeta \quad \text{Equation (2)}$$

Each parameter in block M are indicated as follows:

f_{xy}^o= count for subscriber or thing (in context of IoT) air time,

g_{xy}^o = count for micro-services to subscriber or thing (in context of IoT) requested in a unit MSP also mentioned as M_{xy}^o in expression of Equation (2) and Equation (2A),

β_{xy}^o and γ_{xy}^o respectively provide request stalled to air time and denial of subscriber service pre-allocated to a user equipment. It may be noted, IoT are never assumed to receive denial of services, as they are pre-defined set of services, far limited than a typical customer.

C. Migration Transformation Engine (MTE)

The MTE is the core of implied Pareto transformation, successively iterate the multi-tuple objective function (as exemplify in Section V) to achieve parametric indices, later recognized as KVPIs, depicted in Figure 3. The asymptotic evolution of KVPIs profile is mentioned in Section IV. Starting from baseline transformation successively to some *mth* intermediate or final transformation the constraint equation (2) can be re-written as:

$$\alpha_m(\zeta^m) = \sum_{y=1}^{p}\sum_{x=1}^{q}((f_{xy}^m\, g_{xy}^m\;\; M_{xy}^m) + \beta_{xy}^m + \gamma_{xy}^m \qquad \forall\, p,q\; \in \zeta$$

Equation (3)

IV. COST ELASTICITY COEFFICIENTS

Paving the way towards the 5th Generation (5G) Telecom onto legacy needs evolutionary and revolutionary mobile system design, yet taking into account reduction in up-gradation migration cost [74, 75, 76]. User equipment seamlessly churn the underlying 5G mobility architecture benefits. Cost elasticity coefficients derivatives become the key performance indicators, while data bandwidth is heavily overload with video streams such as BluRay High Definition quality, hence challenge the robustness of our MTE Pareto optimization to gain or approaching towards desired objectives, which strictly impose scenario constraints, as discussed in Section III.

A. Intra MSP Portability Cost Constraints

The iterative cost reduction function must be achieved in a predictable deployment cycle (we use cell management software application [27]), the *mth* iteration in MTE the reduction function φ_p >0, the execution time can be written as:

$$\alpha_m(\zeta^m) = \delta_m \alpha_o(\zeta^o)$$

Equation (4)

Including the constraint driven optimization on Pareto successive wave front $\alpha_m$would be:

$$\alpha_m(\zeta^m) < \alpha_o(\zeta^o)$$

Equation (5)

The less than sign indicates the convergence of cost elasticity with an adaptive choice of δ_m.

B. Use-case MSP Versus MEP Awareness Constraints

The elasticity of cost for baseline (reference scenario in Pareto wave front generation) can easily be deduced from Equation (3) with constraints in Equation (4) to Equation (5). It is mentioned as follows:

$$\mu_o(\zeta^o) = (h_o + h_{on} + h_{om}) \sum_{y=1}^{p} \sum_{x=1}^{q} ((f_{xy}^o\ g_{xy}^o\ M_{xy}^o) + \beta_{xy}^o + \gamma_{xy}^o \qquad \forall\ p,q\ \in \zeta$$

Equation (6)

The wave front offset is evaluated taking into account relative cost for deployment, i.e.

h_o = An idle cost in the state where any user equipment does not request subscribed service.

h_{on} = A cost in the state where any user equipment is monitored for subscribed service.

h_{om} = A cost in the state where any user equipment (IoT) is monitored for subscribed service.

C. Self-Organized Network Configuration Constraints

The reduction function for cost elasticity in successive *mth* transformation would be $\sigma_m > 0$, at any instance of *'m'* MTE parameter would successively reach at

$$\mu_m(\zeta^m) = \sigma_m \mu_o(\zeta^o)$$

Equation (7)

The upper bound of convergence is restricted by the adaptive choice of σ_m in Equation (7). It means adaptive coefficient is operation on the baseline or reference scenario (also known as median of performance benchmark which can be considered to apply linear or nonlinear impact on the resultant successive wave front on the Pareto optimality for lowest (i.e., desired objective) customer-in-loop SCM overheads. The asymptotic cost elasticity coefficient is:

$$\mu_m(\zeta^m) < \mu_o(\zeta^o)$$

Equation (8)

Each iteration aims to achieve a wave front connecting maximum allowable calls as per subscribed services, reduction in air time, lowering user equipment or thing (IoT), bridging mobile service provider participation with a fair priority while rolling over RDC to its minimal objection function as defined in Equation (1).

V. RESULTS AND DISCUSSION

The vulnerability of supply chain management in a mobile service provided tier of 5th Generation networks resource allocation, key performance indicator, migration parameter identification provides a scalable infrastructure up-gradation especially when it comes to cost elasticity, also discussed in this paper and demonstrated for various scenarios [77, 78, 79, 80]. Pareto optimization is performed on Matlab © toolbox [81], so that results and simulation would be consistent across researchers who intend to reproduce the same in Optimization Toolbox. The distribution of subscriber service into various categories in Section III appear to be beneficial over various tiers of MSP versus the MEP deployments or location spread over diversified geo locations, yet consistent with the host MSP, which may and may not in the vicinity of one or more MSPs i.e., while homing or roaming. The most taxing multimedia streaming services are ensure with the DASH-IF multimedia benchmark [9, 25, 57], usually used to rank multimedia players, whether image, audio, video or gaming applications.

A. Platform and Benchmarking Elasticity

We test the framework with 8 sets of streaming application, to demonstrate the robustness in our Elasticity Conformed Mobile Service Provider Systems (EConMSP). All test vectors offer to a candidate environment discreet computational and data bandwidth hungry attitude to challenge its resilience towards higher resolution sampling, high bandwidth throughput and lowest latency when it caters the IP based devices i.e., IoT. Real time traffic data is obtained from [25, 27] on differential or adaptive differential spatial or temporal data packets, broadly known as UWB or OFDM modulation schemes as discussed in [18, 21, 22, 24, 37]

Problem based Scenario: Devices interoperability pose stringent constraints during peak traffic hours at mobile service providers in re-configuration stances, implicitly offer extended cost elasticity in our EConMSP framework.

B. Octet-tuple Dynamics for Constraints Assessments

Imposing constraints to our SON at reduction cost function $\sigma_m \mu_o(\zeta^o)$, where all the factors in Section III are defined as octet-tuple in a space J of typical wave front dimension can be of shape {-1, 0, 1, 1, 1,-1, 1, 0}, interpreted as for served call count, increased air time of call, average service drop in urban area, below average service denials, and low latency self-annealing SON tiers. Intra MSPs portability is always assume available with an allowed latency as mentioned in aforementioned octet-tuple. Referring Figure 2, the iterative formation of wave front bends a rising tuple value (as '1' here) to either '0' or '-1' to meet the objective function in a space J defined in Equation (1).

The inclination of static parameters are constrained slowly than the opposite wave front rise due to dynamic behavior of posed data traffic, but still able to confine itself closed to SCO either of {-1,0,1}. We found the outreach to next wave front always tail the flexibility of deployed or available architecture offering enhanced flexibility when embed with software re-configurability.

It appears in our MTE, successive transformation are not merely random in nature, but follow strictly constraints imposed by $\alpha_m(\zeta^m) < \alpha_o(\zeta^o)$ and hence ensure the convergence. We observe that when MTE reaches to its extreme that is '-1' or '1', the elasticity of scenario constraints bends the wave front node based on their portability, self-organization network tier, and other factors outlines in Section IV.

C. Integration—Unified Migration Framework

Unlike [46, 80, 82, 83] our contribution to ever challenging scenario of technology migration addressing 4th generation MSP to gear up for IoT is demonstrated with following cogent points on the desired elasticity of our EConMSP framework.

First, the order of transformation iteratively depends on the data traffic probability, which needs to be collected over a pre-determined bandwidth demand tenure, hence make it smart choice while retaining offline convergence to predict a migration scenario.

Second, unlike the conventional optimization indices to reach global minima as in aforementioned octet-tuple, proposed framework strictly adheres to scenario constraints, which may not achieve the best solution, but meet desired objectives, provide successively improvement due to self-organization tendency, an inherent attribute of IoT enabled networks.

Third, parametric subtlety conforms to the MSP available scenario whether they are device dependent or device independent, adding more vulnerability eventually. Divergence of wave front could be expected due to high latency, usually imposed by previous 4th generation network limitations during the roaming or homing period of a mobile client (mostly handsets rather than IoT nodes).

Fourth, iteration may distract across the successive wave front carrying an octet-tuple assertion, yet our proposed concept of wave front offsets i.e., $\beta_{xy}^{o}, \gamma_{xy}^{o}$ ensure the specific or imminent divergence within constraints as mentioned in Section IV.

VI. CONCLUSION

The unprecedented evolution of IP based host extended the demand for zero latency, Always Available Always Online, squeezed service infrastructure and grandeur scalability over the diversified mobile service provider tiers. We highlighted here inherent bottlenecks in ever exploiting benefits such as e-Life, to name a few at Mobile Equipment Providers (MEP) tier, are complemented at Device Dependent Device Independent (D3I) configuration inherent in Mobile Service Providers (MSP). We encourage strategies enabling a Supply Chain Management (SCM) augment a unique systems support involving the MSPs and MEPs for desired Customer Relationship Management (CRM), Ad hoc Resource Planning (ARP), which we found prevalent in migration scenario from 4G to 5G technology deployment. We demonstrate flexibility of Pareto multi-criteria optimization, to find the strategic indicators which are primary Transformation Steering Factors (TSF), valid in both device dependent or device independent M2M migration. Our MTE in line with the transformation vector space exhibit trail of Pareto wave fronts, where each iteration aims to achieve a wave front connecting maximum allowable calls as per subscribed services, reduction in air time, lowering user equipment or thing (IoT), bridging mobile service provider participation with a fair priority while rolling over RDC to its minimal objection function.

Proposed framework is flexible to exploration of different avenues in ad hoc networking, wireless sensor networks and customized scenario where hybrid mobile services are desired, integrated in diversified generations as 2nd generation onto 5th generation. Our exposed results would encourage network layout research in wired or wireless mobile service industry to assess the migration elasticity cost after choosing canned set of migration transform octet-tuple to desired goal-driven objectives over the successive Pareto wave front. We also intended to extend the MTE optimization framework across the large number of constraints, evaluation across other optimization techniques, such as multi-criteria statistical or stochastic processing tools.

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