Note on Evolution and Forecasting of Requirements: Communications Example

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Combinatorial evolution and forecasting of system requirements is examined. The morphological model is used for a hierarchical requirements system (i.e., system parts, design alternatives for the system parts, ordinal estimates for the alternatives). A set of system changes involves changes of the system structure, component alternatives and their estimates. The composition process of the forecast is based on combinatorial synthesis (knapsack problem, multiple choice problem, hierarchical morphological design). An illustrative numerical example for four-phase evolution and forecasting of requirements to communications is described.

Keywords: Modular system, requirements, communications, evolution, forecasting, decision making, combinatorial optimization

1. Introduction

Recently, the significance of evolution and forecasting for communication systems has been increased (Table 1).

Table 1. Some modeling problems for evolution, history evolution in communications

| No. | Study                                                                 | Source(s) |
|-----|----------------------------------------------------------------------|-----------|
| 1.  | Modeling of topology evolutions and implication on proactive routing overhead in MANETs | 36        |
| 2.  | Historical evolution of software defined networking (SDN), its architecture | 14,35     |
| 3.  | Intellectual history of programmable networks (SDN)                  | 6,31,30   |
| 4.  | History and challenges in network function virtualization            | 4,30      |
| 5.  | Engineering descriptions of evolution and challenges for wireless systems $(G0 \rightarrow G1 \rightarrow G2 \rightarrow G3 \rightarrow G4 \rightarrow G5 \rightarrow G6)$ | 11,11,129 |
| 6.  | Analysis of challenges and opportunities for next generation of mobile networks | 3,3,10    |

In general, the following three-layer framework can be examined (Fig. 1): (i) system requirements, (ii) standards, (iii) system(s)/product(s). As a result, the problems of system evolution and forecasting can be examined for each of the above-mentioned layers of communications (i.e., system requirements, standards, system(s)/product(s)).

The article addresses combinatorial evolution and forecasting of requirements to communications (Table 2). The study of modular systems (systems, standards, system requirements) is based on morphological

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model (a set of part/components, set of design alternatives (DAs) for each part/component above, and ordinal estimates of DAs) \[17,19,23\]. The system composition process is based on qualities of the selected DAs and qualities of their interconnections (compatibilities) (IC). The system composition is considered as combinatorial synthesis (knapsack problem, multiple choice problem, hierarchical morphological multicriteria design approach HMMD) \[17,19,23\]. The author’s approach to combinatorial evolution and forecasting has been described in \[17,18,19,20,22,23\]. The corresponding applied examples of the approach are pointed out in Table 3. The presented illustrative numerical example for four-phase evolution and forecasting of communications requirements to network topology can be considered as a basis for analogical studies in communications and other domains.

### Table 2. Some problems over requirements

| No. | Problems                                                                 | Source(s) |
|-----|---------------------------------------------------------------------------|------------|
| 1.  | Study, design/generation of system requirements                           | [7,28,32]  |
| 2.  | Modeling of requirements (e.g., hierarchical modeling)                   | [15,20]    |
| 3.  | Monitoring of requirements                                               | [12]       |
| 4.  | Management requirements for network function virtualization             | [2]        |
| 5.  | Modeling of evolution for requirements                                   | [15,20]    |
| 6.  | Forecasting of requirements                                              | this paper |

### Table 3. Applications of combinatorial evolution and forecasting

| No. | Applied system                                                                 | Evolution | Forecasting | Source(s) | Year |
|-----|--------------------------------------------------------------------------------|-----------|-------------|-----------|------|
| I.  | Systems/products:                                                             |           |             |           |      |
| 1.1 | Architecture of DSS COMBI-PC                                                  | Yes       | None        | [16,17]  | 1993 |
| 1.2 | Electronic device for signal processing                                        | Yes       | None        | [19,21]  | 2000 |
| II. | Standards:                                                                    |           |             |           |      |
| 2.1 | MPEG-like standard for multimedia information transmission                    | Yes       | Yes         | [23,25]  | 2009 |
| 2.2 | ZigBee protocol for sensor networks                                           | Yes       | Yes         | [23,26,27] | 2010 |
| III. | Modular educational courses:                                                  |           |             |           |      |
| 3.1 | Education course on system engineering/system design                          | Yes       | Yes         | [22,23]  | 2013 |
| IV. | System requirements:                                                          |           |             |           |      |
| 4.1 | Requirements to communications topology (morphological model with design alternatives) | Yes     | None        | [15,20]  | 2005 |
| 4.2 | Requirements to communications topology                                      | Yes       | Yes         | this paper | 2017 |

### 2. Framework of combinatorial system evolution and forecasting

Knowledge representation in product design systems is systematically studied (e.g., [3,9]). Here, modular systems (or corresponding modular/composite alternatives/solutions) are examined as the following (i.e., system configuration) (e.g., [19,23]): (a) a set of system elements (parts, components, modules), (b) a special structure over the system elements, e.g., hierarchy, tree-like structure. In addition, system element alternatives can be considered (including estimates of the alternatives).

Fig. 2 depicts a composite (modular) system, consisting of \( n \) parts/components/modules \((P^n, i = 1, n)\) and corresponding three design alternatives (DAs) for each part/component/module \( P^i \) \[17,19,23\]. For DAs, the following information is considered (i.e., morphological system structure) (e.g., [17,19,23]): (a) estimates of DAs (e.g., vector estimates, ordinal estimates, interval multiset estimates), (b) estimates of compatibility between DAs of different system components (e.g., ordinal estimates, interval multiset estimates).

Generally, the following system change operations types can be studied and used \[17,18,19,21,23\]:

**I.** Operations for DAs: 1.1. change/improvement of DA \( O_1 \), 1.2. deletion of DA \( O_2 \), 1.3. addition of DA \( O_3 \), 1.4. aggregation of DAs \( O_4 \).

**II.** Operations for IC: change/improvement of DAs compatibility IC \( O_5 \).

**III.** Operations for subsystems (system parts, components): 3.1. change/improvement of a system part \( O_6 \), 3.2. deletion of a system part \( O_7 \), 3.3. addition of a system part \( O_8 \), 3.4. aggregation of system parts \( O_9 \).
IV. Operations for the system configuration/structure (change/extension): \((O_{10})\).

For each operation above, a set of attributes has to be examined (e.g., required resources, profit). Special binary relations over the operations can be examined as well (e.g., compatibility, complementarity) \([19]\). As a result, the improvement process can be considered as selection and/or composition of the above-mentioned operations (items) while taking into account objective function(s) and resource constraint(s). This process can formulated as designing an improvement configuration (e.g., knapsack problem, multiple choice problem, HMMD). The considered scheme of system evolution and forecasting involves the following stages (Fig. 3) \([18,19,22,23]\):

![Diagram](image_url)

**Stage 1.** Analysis of chain of system generation and detection of system changes between neighbor system generations.

**Stage 2.** Integration of system changes into a general set of the changes (change operations/items) while taking into account expert judgment.

**Stage 3.** Selection/generation of a “basic” system, for example as the next existing system generation.

**Stage 4.** Design of forecast as combinatorial modification of the basic system: system reconfiguration on the basis of combinatorial synthesis of change items (e.g., knapsack problem, multiple choice problem, HMMD).

3. Example for evolution and forecasting of requirements

The illustrative example of combinatorial system evolution and forecasting is considered on the basis of initial data from \([15,20]\). The following traditional network hierarchy can be examined: (a) international (multi-country, continent) network (GAN), (b) metropolitan network (MN), (c) wide area network (WAN), and (d) local area network (LAN). Here, four generations for communication networks (i.e., network topological structure) are considered:

**Generation 1.** Simple minimum cost network as one-connected structure (e.g., minimum cost spanning tree or minimum Steiner tree).
**Generation 2.** Reliable network (e.g., bi-connected graph).

**Generation 3.** Survivable network (e.g., bi-connected graph with additional links).

**Generation 4.** Multi-layer GRID-like network environment (flexible, upgradeable network with reconfigurable topology).

The corresponding tree-like hierarchy of requirements to the network (network topology) above is:

**Part 1.** User requirements $A$:
- 1.1. time of transmission $T$.
- 1.2. quality (information errors, reliability of connection) $Q$.
- 1.3. cost of transmission $W$.

**Part 2.** System requirements $B$:
- 2.1. Basic criteria $I$: 2.1.1. cost $J$, 2.1.2. reliability $R$, 2.1.3. manageability $H$, 2.1.4. maintainability $V$, 2.1.5. testability $E$, 2.1.6. modularity $M$.
- 2.2. Dynamic criteria $Y$: 2.2.1. adaptability $L$, 2.2.2. safety $F$, 2.2.3. flexibility $K$.

**Part 3.** Mobility requirements $C$.

**Part 4.** Evolution/development requirements $D$:
- 4.1. upgradeability $U$.
- 4.2. closeness to grid $Z$.

For each leaf node of the structure above, the following design alternatives (DAs) (as levels of satisfiability) are examined: none ($X_0$), low level ($X_1$), medium level ($X_2$), and high level ($X_3$). The four-phase evolution of the hierarchical requirements structure is depicted in Fig. 4, Fig. 5, Fig. 6, and Fig. 7 (DAs as $X_0$ is absent).
The modular presentations of requirements are:

Generation 1: \( S_1^1 = A_1^1 \times B_1^1 \times C_1^1 \times D_1^1 = \)
\( (T_1 \times Q_1 \times W_1) \times (J_1 \times R_1 \times H_1 \times V_0 \times E_0 \times M_0) \times (L_0 \times F_0 \times K_0) \times C_0 \times (U_0 \times Z_0). \)

Generation 2: \( S_2^2 = A_2^1 \times B_2^1 \times C_2^1 \times D_2^1 = \)
\( (T_2 \times Q_2 \times W_2) \times (J_1 \times R_2 \times H_1 \times V_1 \times E_1 \times M_1) \times (L_1 \times F_0 \times K_0) \times C_0 \times (U_1 \times Z_0). \)

Generation 3: \( S_3^3 = A_3^1 \times B_3^1 \times C_3^1 \times D_3^1 = \)
\( (T_2 \times Q_2 \times W_2) \times (J_3 \times R_2 \times H_2 \times V_3 \times E_2 \times M_1) \times (L_2 \times F_1 \times K_1) \times C_0 \times (U_1 \times Z_0). \)

Generation 4: \( S_4^4 = A_4^1 \times B_4^1 \times C_4^1 \times D_4^1 = \)
\( (T_2 \times Q_3 \times W_2) \times (J_3 \times R_2 \times H_2 \times V_3 \times E_2 \times M_2) \times (L_2 \times F_1 \times K_1) \times C_1 \times (U_2 \times Z_1). \)

The local changes of the requirements with estimates upon two criteria (cost of change, 0 is the best value; profit of change, the maximum value is the best one; expert judgment) are presented in Table 4, Table 5, and Table 6.

Now \( S^4 \) is considered as a basis for the forecasting. A set of prospective change operations/items (improvements, DAs) is contained in Table 7 (ordinal priorities of DAs are based on the use of multicriteria ranking, priority ordinal scale is \([1,3])\). HMMD is used [17,19,23]. The best composition of the change operations (improvements) is searched for as the forecast of the system requirement. The hierarchical structure of the composite system improvement is depicted in Fig. 8. Table 8 and Table 9 contain ordinal estimates of compatibilities between DAs (ordinal scale \([0,3])\). Finally, two Pareto-efficient composite improvements are (it is assumed composite DAs for \( A^l, B^l, D^l \) are compatible):

(i) \( S_1^l = A_1^1 \times (B_1^1 \times B_2^1) \times (D_2^1 \times D_3^1 \times D_4^1) \), here \( N(B_1^1) = (3;2,0), N(D_1^1) = (3;2,1,0) \); (ii) \( S_2^l = A_1^1 \times (B_2^1 \times B_2^1) \times (D_3^1 \times D_3^1 \times D_4^1) \), here \( N(B_1^1) = (3;2,0), N(D_2^1) = (2;3,0,0) \).

### Table 4. Change operations for \( S^1 \Rightarrow S^2 \)

| No. | Change operation | Cost | Profit |
|-----|-----------------|------|--------|
| 1.  | \( J_1 \rightarrow J_2 \) | 1.5  | 1.5    |
| 2.  | \( R_1 \rightarrow R_2 \) | 2.0  | 2.5    |
| 3.  | \( T_1 \rightarrow T_2 \) | 2.2  | 3.0    |
| 4.  | \( Q_1 \rightarrow Q_2 \) | 1.6  | 2.0    |
| 5.  | \( W_1 \rightarrow W_2 \) | 1.5  | 1.4    |
| 6.  | \( V_0 \rightarrow V_1 \) | 2.0  | 2.1    |
| 7.  | \( E_0 \rightarrow E_1 \) | 1.4  | 1.7    |
| 8.  | \( M_0 \rightarrow M_1 \) | 1.9  | 1.5    |
| 9.  | \( L_0 \rightarrow L_1 \) | 1.8  | 1.5    |
| 10. | \( U_0 \rightarrow U_1 \) | 2.0  | 1.6    |

The corresponding two resultant system requirements forecasts are:

(i) \( S_1^F = A_1^F \times B_1^F \times C_1^F \times D_1^F = \)
\( (T_2 \times Q_3 \times W_2) \times (J_3 \times R_2 \times H_2 \times V_3 \times E_3 \times M_3) \times (L_2 \times F_2 \times K_3) \times C_1 \times (U_2 \times Z_3) \); (ii) \( S_2^F = A_1^F \times B_2^F \times C_1^F \times D_2^F = \)
\( (T_2 \times Q_3 \times W_2) \times (J_3 \times R_2 \times H_2 \times V_3 \times E_3 \times M_3) \times (L_2 \times F_3 \times K_3) \times C_1 \times (U_2 \times Z_3) \).

### Table 5. Change operations for \( S^2 \Rightarrow S^3 \)

| No. | Change operation | Cost | Profit |
|-----|-----------------|------|--------|
| 1.  | \( H_1 \rightarrow H_2 \) | 2.5  | 2.5    |
| 2.  | \( V_1 \rightarrow V_2 \) | 2.2  | 2.4    |
| 3.  | \( E_1 \rightarrow E_2 \) | 1.5  | 2.0    |
| 4.  | \( L_1 \rightarrow L_2 \) | 1.5  | 1.8    |
| 5.  | \( F_0 \rightarrow F_1 \) | 1.4  | 2.0    |
| 6.  | \( K_0 \rightarrow K_1 \) | 1.5  | 2.1    |
Table 6. Change operations for $S^3 \Rightarrow S^4$

| No. | Change operation | Cost | Profit |
|-----|------------------|------|--------|
| 1.  | $Q_2 \rightarrow Q_3$ | 2.1  | 3.0    |
| 2.  | $J_2 \rightarrow J_3$ | 1.7  | 2.0    |
| 3.  | $M_1 \rightarrow M_2$ | 1.6  | 1.8    |
| 4.  | $U_1 \rightarrow U_2$ | 1.8  | 2.0    |
| 5.  | $C_0 \rightarrow C_1$ | 2.8  | 3.0    |
| 6.  | $Z_0 \rightarrow Z_1$ | 1.5  | 2.0    |

Table 7. Prospective improvement for $S^4$

| No. | Change operation/item | Cost | Profit | Priority |
|-----|-----------------------|------|--------|----------|
| I.  | Part A:               |      |        |          |
| 1.1 | $A_1$: none           | 0    | 0      | 2        |
| 1.2 | $A_2$: $W_2 \rightarrow W_3$ | 1.4  | 1.6    | 1        |
| II. | Part B:               |      |        |          |
| 2.1.1| $B_1$: none           | 0    | 0      | 3        |
| 2.1.2| $B_2$: $E_2 \rightarrow E_3$ | 2.0  | 2.1    | 1        |
| 2.2.1| $B_1$: none           | 0    | 0      | 3        |
| 2.2.2| $B_2$: $M_2 \rightarrow M_3$ | 1.6  | 1.9    | 1        |
| III. | Part D:               |      |        |          |
| 3.1.1| $D_1$: none           | 0    | 0      | 3        |
| 3.1.2| $D_2$: $F_1 \rightarrow F_2$ | 1.7  | 2.1    | 2        |
| 3.1.3| $D_3$: $F_1 \rightarrow F_3$ | 2.1  | 3.9    | 1        |
| 3.2.1| $D_1$: none           | 0    | 0      | 3        |
| 3.2.2| $D_2$: $K_1 \rightarrow K_2$ | 1.5  | 2.0    | 2        |
| 3.2.3| $D_3$: $K_1 \rightarrow K_3$ | 3.0  | 4.1    | 1        |
| 3.3.1| $D_1$: none           | 0    | 0      | 3        |
| 3.3.2| $D_2$: $Z_1 \rightarrow Z_2$ | 1.6  | 2.0    | 2        |
| 3.3.3| $D_3$: $Z_1 \rightarrow Z_3$ | 2.1  | 4.1    | 1        |

Composite improvement $S^I = A^I \ast B^I \ast D^I$

$S^I_1 = A_1 \ast (B_2 \ast \widehat{B}_2) \ast (D_2 \ast \widehat{D}_3 \ast \overline{D}_3)$

$S^I_2 = A_1 \ast (B_2 \ast \widehat{B}_2) \ast (D_3 \ast \widehat{D}_3 \ast \overline{D}_3)$

$D^I_1 = \widehat{D}_2 \ast \widehat{D}_3 \ast \overline{D}_3$

$A^I_1 = A_1 \ast B^I_1 = \widehat{B}_2 \ast \widehat{B}_2 \ast \overline{D}_3 \ast \widehat{D}_3 \ast \overline{D}_3$

$A^I_2 = A_2 \ast B^I_2 = \widehat{B}_2 \ast \widehat{B}_2 \ast \overline{D}_2 \ast \widehat{D}_2 \ast \overline{D}_2$

Fig. 8. Resultant structure of system improvement
4. Conclusion

The paper describes our first integrated step to combinatorial evolution and forecasting of requirements to communications. A hierarchical morphological model of the requirements system is used. Forecasting is based on morphological design approach (selection/composition of the best change items while taking into account their compatibility). The future research directions can involve the following: examination of the suggested approach to generations of wireless communications systems and the requirements to the systems.

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REFERENCES

1. M.R. Bhala, A.V. Bhala, Generations of mobile wireless technology: A survey. Int. J. of Computer Applications, 5(4), 26–32, 2010.
2. L. Bondan, C.R.P.d. Santos, L.Z. Granville, Management requirements for ClickOS-based Network Function Virtualization. In: 2014 10th Int. Conf. on Network and Service Management (CNSM), pp. 447–450. 2014.
3. S.K. Chandrasegaran, K. Ramani, R.D. Sriram, I. Horvath, A. Bernard, R.F. Harik, W. Gao, The evolution, challenges, and future of knowledge representation in product design systems. CAD, 45(2), 204–228, 2013.
4. N.M.K. Chowdhury, R. Boutaba, A survey of network virtualization. Computer Networks, 54(5), 862–876, 2010.
5. O.O. Fagbohun, Comparative studies on 3G, 4G and 5G wireless technology. IOSR J. of Electronics and Communication Engineering, 9(3), 88–94, 2014.
6. N. Feamster, J. Rexford, E. Zegura, The road of SDN: an intellectual history of programmable networks. ACM SIGCOMM Comput. Commun. Rev., 44(2), 87–98, 2014.
7. D.M. Ferbandez, S. Wagner, Naming the pain in requirements engineering: A design for a global family of surveys and first results from Germany. Information and Software Technology, 57, 616–643, 2015.
8. B. Han, V. Gopalakrishnan, L. Ji, S. Lee, Network function virtualization: Challenges and opportunities for innovation. IEEE Communications Magazine, 53(2), 90–97, 2015.
9. C.T. Hansen, A. Riitahuhta, Issues on the development and application of computer tools to support product structuring and configuring. Int. J. of Technol. Manag., 21(3/4), 240–256, 2001.
10. H. Hawilo, A. Shami, M. Mirahmadi, R. Asal, NFV: state of the art, challenges, and implementation in next generation mobile networks (vEPC). IEEE Networks, 28(6), 18–26, 2014.
11. M.G. Kachhavay, A.P. Thakare, 5G technology-evolution and revolution. Int. J. of Computer Science and Mobile Computing, 3(3), 1080–1087, 2014.
12. I. Karakatsanis, W. AlKhader, F. MacCrory, A. Alibasic, M. Atif Omar, Z. Aung, W.-L. Woon, Data mining approach to monitoring the requirements of the job market: A case study. Information Systems 65, 1–6, 2017.
13. Y. Koren, U. Heisel, F. Jovane, T. Moriwaki, G. Pritzschow, G. Ulsoy, H. Van Brussel, Reconfigurable manufacturing systems. CIRP Ann. Manuf. Technol., 48(2), 527–540, 1999.
14. D. Kreutz, F.M.V. Ramos, P.E. Verissimo, C.E. Rothenberg, S. Azodolmolky, S. Uhlig, Software-defined networking: A comprehensive survey. Proc. of the IEEE, 103(1), 14–76, 2015.
15. N.A. Kuznetsov, M.S. Levin, V.M. Vishnevsky, Some Combinatorial Optimization Schemes for Multi-Layer Network Topology. In:Paris, France, Paper T4-I-42-0486, 2005.
16. M.Sh. Levin, Hierarchical components of human-computer systems. LNCS 753, Springer, pp. 37–52, 1993.
17. M.Sh. Levin, Combinatorial Engineering of Decomposable Systems. Springer, 1998.
18. M.Sh. Levin, Combinatorial evolution of composite systems. In: 16th Eur. Meeting on Cybern. and Syst. Res., vol. 1, Austria, pp. 275–280, 2002.
19. M.Sh. Levin, Composite Systems Decisions. Springer, 2006.
20. M.Sh. Levin, Combinatorial technological systems problems (examples for communication system). In: Proc. of Int. Conf. on Systems Engineering and Modeling ICSEM-2007, Israel, pp. 24–32, 2007.
21. M.Sh. Levin, Towards communication network development (structural system issues, combinatorial models). In: 2010 IEEE Region 8 Int. Conf. “SIBIRCON-2010”, vol. 1, pp. 204–208, 2010.
22. M.Sh. Levin, Towards combinatorial evolution of composite systems. Expert Systems with Applications, 40(4), 1342–1351, 2013.
23. M.Sh. Levin, Modular System Design and Evaluation, Springer, 2015.
24. M.Sh. Levin, B.J. Feldman, System evolution: Example for signal processing. In: Proc. of 14th Intl. Conf. on Systems Engineering ICSE2000, Coventry Univ., UK, pp. 377–380, 2000.
25. M.Sh. Levin, O. Kruchkov, O. Hadar, E. Kaminsky, Combinatorial systems evolution: example of standard for multimedia information. Informatica, 20(4), 519–538, 2009.
26. M.Sh. Levin, A. Andrushevich, R. Kistler, A. Klapproth, Combinatorial evolution of ZigBee protocol. 2010 IEEE Region 8 Int. Conf. SIBIRCON-2010, vol. 1, pp. 314–319, 2010.
27. M.Sh. Levin, A. Andrushevich, R. Kistler, A. Klapproth, Combinatorial evolution and forecasting of communication protocol ZigBee. Electr. prepr., 6 p., Apr. 15, 2012, http://arxiv.org/abs/1204.3259 [cs.NI]
28. P. Loucopoulos, V. Karakostas, System Requirements Engineering. McGraw Hill, 1995.
29. H. Mehta, D. Patel, B. Joshi, H. Modi, 0G to 5G mobile technology: A survey. J. of Basic and Applied Engineering Research, 1(6), 56–60, 2014.
30. R. Mijumbi, J. Serrat, J.-L. Gorricho, N. Bouten, F. De Turck, R. Boutaba, Network Function Virtualization: State-of-the art and Research Challenges. IEEE Communications Surveys & Tutorials, 18(1), 236–262, 2016.
31. B.A.A. Nunes, M. Mendinca, X.-N. Nguen, K. Obraszka, T. Turletti, A survey of software-defined networking: past, present, and future of programmable networks. IEEE Commun. Surv. Tutor., 16(3), 1617–1634, 2014.
32. K. Pohl, Requirements Engineering: Fundamentals, Principles, and Techniques. Springer, 2010.
33. P. Sharma, Evolution of mobile wireless communication networks - 1G to 5G as well future prospective of next generation communication network. Int. J. of Comp. Sci. and Mob. Comput., 2(8), 47–53, 2013.
34. A.P. Singh, S. Nigam, N.K. Gupta, A study of next generation wireless network 6G. Int. J. of Innovative Research in Computer and Communication Engineering, 4(1), 871–874, 2007.
35. S. Singh, Rakesh Kumar Jha, A survey on software defined networking: Architecture for next generation network. J. of Network and Systems Management, Sep. 2016. (in press)
36. X. Wu, H.R. Sadjadpour, J.J. Garcia-Luna-Aceves, Modeling of topology evolutions and implication on proactive routing overhead in MANETs. Computer Communications, 31(4), 782–792, 2008.