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Clustering in Cognitive Radio Networks: A Review

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Abstract— To overcome the drawback of underutilisation of the spectrum in wireless communication field, the Cognitive Radio (CR) technology came into existence, which permits the unlicensed or the Secondary Users (SU) to opportunistically use the available licensed spectrum when the licensed or the Primary User (PU) is not in use. The unlicensed user should not disrupt the working of the licensed user. To reduce the problem of shadowing and fading in CR, cooperative sensing was introduced in which many Cognitive Radio Users (CR Users) collectively report their decisions or data to the Fusion Center (FC) and it makes the final decision regarding the absence or presence of PU. In cooperative sensing, larger overhead is observed. Hence, clustering is one of the methods which reduces overhead. Clustering is a topology management system, in which the nodes are organized into logical groups known as clusters. It not only boosts the performance of the network but also achieves network scalability and stability, supports cooperative tasks, reduces the bandwidth requirement. This paper reviews the numerous clustering schemes, analyzes their characteristics and studies their performances.

Keywords— Cognitive radio, Cooperative spectrum sensing (CSS), Clustering, Cluster head, Fusion centre, Probability of detection, Probability of false alarm.

I. INTRODUCTION

Cognitive Radio (CR) is a rising technology which provides CR users or the Secondary Users (SU) access to unused licensed spectrum bands of the primary user, when it is not in use. The fundamental requirement for the SU is to use an effective Spectrum Sensing (SS) technique which keeps on observing the PU's activity and once the PU attempts to use that, the SU should immediately vacate the band. The major hindrance in implementing SS is the 'hidden terminal problem', in which the SUs are unable to differentiate between an idle and a deeply faded or shadowed band [1]. Cooperative Spectrum Sensing (CSS) is employed to overcome this problem [2,3].

The cooperation between the nodes is synchronized by the Fusion Center (FC). The SUs send their data or decision to the fusion center at each sensing interval. At the FC, final decision about the presence or absence of PU is made by combining all the local sensing data using an optimal fusion rule [4,5,6]. For reporting the decisions to the FC, the CSS is marked by high sensing delay, high energy consumption and high overhead [7]. To overcome these problems, the clustering scheme came into existence.

Clustering is a phenomenon in which the sensing nodes are arranged into logical groups, known as clusters, which provides wide performance enhancement of the network. The formation of the clusters depends on various factors viz. the geographical location, channel availability, SNR etc. Each cluster comprises mainly three types of nodes which are cluster head, member node and gateway node. Out of all the member nodes, one is selected as Cluster Head (CH) based on some parameters like the one with a higher reliability, higher SNR or high energy, higher node degree level, lower no. of hops etc. The rest of the secondary are known as member nodes. Each of the member nodes senses the channel availability independently through energy detection and report their data or decision to the cluster head [8].

The cluster head has multiple roles such as routing, making final decisions for the clusters, scheduling of CR users to access the available channel in a certain manner, and coordinating cluster member's spectrum sensing procedure. The cluster head and the member nodes interact often and provide us with the intra-cluster communications. The gateway nodes are also the member nodes which are located at the verge of the cluster and can communicate with the neighbouring clusters, so they provide inter-cluster

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communications. The gateway node keeps on switching its operating channel [8].

Each of the SU performs the spectrum sensing process at their individual level before reporting to the FC, known as local spectrum sensing. This process is a binary hypothesis testing problem i.e. the presence or absence of PU. Energy detection is the best technique to be used for this purpose as it is the simplest one out of all, quick, able to sense the primary signal easily even if none of the feature of the signal is known. [9]

There are many clustering algorithms, each one of them having their own clustering strategy. The main difference between various algorithms is the selection of cluster heads and how the various sensing nodes relate among themselves. The cluster formation process is initiated by a node when it fails to find any clusters nearby. To form clusters, local information is exchanged among the neighbouring nodes such as the list of available channels etc. Dynamicity of the channel availability is one of the major challenges linked with clustering. Re-clustering is often performed with change in the clustering conditions.

Objectives of clustering:
The main clustering objectives are establishment of common control channel, refining of cluster stability, energy efficiency, and cooperative task and minimizing the number of clusters. The major clustering metrics are channel availability, geographical location, strength of the signal, channel quality, node degree, single hops and multiple hops.

Advantages of clustering:
There are various advantages of clustering such as scalability, stability, cooperative task support. Through the reduction in the communication overhead and parallelism, the scalability is said to be improved. The stability is the drop in the global effects with the changes in the network environment like the availability of the channel or the network topology. With the dynamicity of the network the local updates keep on happening among sensing nodes and their respective cluster heads. The cooperative ask include channel switching, channel sensing and routing to enhance network performance.

The paper below is arranged in the following manner: section 2 represents the review of various clustering schemes, their parameters, advantages, disadvantages; section 3 represents the various challenges associated with the clustering and finally section 4 represents the conclusion of the paper.

II. RELATED WORK

The clustering scheme proposed by Nhan Nguyen-Thanh et. al. [10], reduces reporting time and bandwidth and maintains a particular level of sensing performance, reduces energy consumption. Based on the identification of primary SNR values, the clusters are organized. The cluster head is chosen dynamically according to the quality of the sensing data. An optimal threshold is chosen to make the cluster sensing decision [11,12], which also minimizes the sensing error and the decision is made at the FC according to the selective method [11,13]. A parallel reporting mechanism is also introduced based on frequency division and reduces reporting time. To obtain high sensing performance “Chair-Varshney rule” is used [14].

Yan Jiao et. al. [15], divided the clustering into three stages viz. pruning, selecting and clustering. In the pruning stage the no decision CR users are excluded for the clusters formation [16]. The CR users with the most reliable data are selected as cluster head in the selecting stage and the reliability is judged on the basis of likelihood function [10]. Then, considering the mobility of the CR users, clustering is done based on the correlation of SS results. To reduce the overhead change point detection mechanism is adopted [17]. To detect change point, affinity program is discussed [18]. This scheme reduces overhead as well as improves energy efficiency. This also suits to perform in low SNR environment.

Multi-cluster multi-group based sensing scheme is proposed by Wonsop Kim et. al. [19]. Clustering is done using distributive clustering algorithm [20]. Optimal number of groups is obtained using “K out of N rule” [4-6]. The largest control channel gain sensor is selected as the group head. Total error rate of the CR network is improved

To tackle the trade off between performance and overhead, Faroq A. Awin et. al. [21] proposes a multi level hierarchical structure algorithm. This algorithm deals with the large number of sensors and is energy efficient. To reduce overhead, double fusion stages are involved. A cluster is divided into optimal groups [19] and the groups are further divided into further subgroups. The subgroup head is selected by polling and the group head is said to have largest reporting channel gain [22,23]. An iterative algorithm is discussed to obtain optimal number of groups and subgroups. Also optimal fusion rule [4-6], optimal threshold [6,24] and energy efficiency [6] is derived for good sensing performance. Energy is saved up to 70% and overhead is also reduced to a great extent [25,26].

Unsupervised archetypal clustering is proposed by Balaji V et. al. [27] is based on machine learning. The local energy vectors are decomposed into archetypes, which are the collection of extreme points [28]. This provides an extreme view of the data. The cluster heads are chosen randomly and are determined by clustering the SU’s using archetypal analysis. The performance is quantified in terms of target probability of detection false alarm, to meet the requirement

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of IEEE 802.22 WRAN standard parameters. CSS scheme here is modelled under path loss and shadowing atmosphere. 82% probability of detection is achieved for 0.1 target false alarm probability. Low classification delay is observed.

X. Fernando et. al. [29], addressed the band limitation problem of the reporting channels. By reducing the number of reporting terminals at the fusion terminals to a minimum reporting set, the bandwidth is minimized. The distributed SS scheme here eradicates the need for the base station and substitute it with the local fusion centre. Using general centre scheme in graph theory [30], the location of fusion centre is selected. To get the minimal set of clusters, the minimal dominating set (MDS) algorithm is used [31, 32], which gives a minimum false alarm probability and maximum per node throughput. The scheme chooses the user with the highest reporting channel gain from a set of neighbouring nodes that share a channel with the maximum degree as the cluster head. The effect of number of clusters, cluster size, probability of reporting channel errors, sensing time on per node throughput capacity is studied. The results show that for good performance it is not compulsory to incorporate all the secondary users under bad conditions. A lower bound of cluster radius is determined that keeps the number of isolated nodes under an upper limit. The highest reporting channel gain node is selected as the cluster head.

The issues associated with the mobile networks are addressed by Akif Cem Heren et. al. [33]. Clusters are formed by using novel energy and congestion efficient MAC layer protocol. To save the energy, the number of reports those offer less additional information are eliminated from the network using low power whispering protocol. Along with the reduction in overall energy expenditure, the lifetime of SUs is also increased, the accuracy and fairness is preserved. Up to 30% of energy is saved. The cluster heads are selected based on the quality of reception of PU i.e. the strength of spectrum measurement.

More energy is required for a cluster head to report its decision to the fusion centre when FC lies far away from it. This issue is considered by Ahmed S. B. Kozal et. al. [34]. A multi-hop cluster-based CSS scheme is introduced which reduces the power consumption but at the expense of slight increase in the reporting time. Total clusters are divided into multi levels. The sensing delay and energy consumption parameters are studied which are then compared with the existing schemes. The SU with the highest reporting channel's SNR is chosen as cluster head [35]. The proposed method significantly reduces the energy consumption and detects the spectrum availability much faster. The simulation results show that to design a good spectrum sensing technique, the trade-off between sensing delay and energy consumption need not to be considered.

To decrease the bandwidth limitations in CRN using energy detection, a Rely Factor (R-F) based scheme with cluster based CSS is proposed by T. Rasheed et. al. [36]. The R-F consists of factors like SNR, threshold of energy detector of each sensor node, local sensing difference. To enhance the detection performance of the nodes, all these factors are combined using fuzzy logics [29]. The comparative analysis shows that the results are better than the existing scheme which is in the form of ROC. An improvement in the detection probability along with the reduction in miss detections is observed.

Santi P. Maity et. al. [37] proposed an optimal Fuzzy C-Means clustering based on energy detection for CSS [38]. The binary hypothesis problem here is considered as a multiple class problem that are: strong, moderate, weakly presence, absence of PU, which is then followed by binary fusion. Two methods are proposed. One, Differential Evolution (DE) is used to find optimal cluster center points, which maximizes the reliability [39]. Results show high detection probability is achieved at lower SNRs and lower false alarm probability, which shows improved ROC and good performance gain. Two, the average SU energy consumption is minimized while retaining the predefined sensing reliability by determining the optimal SU amplifying gain and optimal number of PU samples [40]. Based on a sensor's location within each cluster, its position with respect to FC, its SNR and its residual energy, the cluster head is selected.

At low signal-to-noise ratios (SNR) and in the presence of multiple PUs, the performance of [37] degrades, as energy data patterns at the FC are often found to be non-spherical i.e. overlapping. This problem is addressed by Anal Paul et. al. [41]. Through the projection of non-linear input data to a high dimensional feature space, the scope of kernel fuzzy c-means clustering is explored. This scheme provides a high detection probability for single PU, up to 0.9 and for multiple PUs, up to 0.86, the average energy consumption is also reduced. Based on a sensor's location within each cluster, its position with respect to FC, its SNR and its residual energy, the cluster head selected.

Table 1. Comparative analysis of various clustering schemes

Author	Cluster head selection	Advantages
Nhan Nguyen et. al. 2013 [10]	Node with best quality of sensing data	Reporting time, bandwidth, energy consumption, and error, overhead reduces and sensing performance is maintained.
Yan Jiao et. al. 2016 [15]	Node with most reliable sensing data	Overhead reduces, energy efficiency increases, performs in low SNR environment.
Wonsop Kim et. al.	Node with largest	Error rate is improved,

2010 [19]	control channel gain as group head	overhead is reduced.
Faroq A. Awin et. al. 2014 [21]	Subgroup head by polling. Group head with largest reporting channel gain	Energy efficient, sensing performance is increased, overhead is reduced.
Balaji V et. al. 2016 [27]	Chosen randomly	Delay and overhead reduces.
X. Fernando et. al. 2012 [29]	Node with highest reporting channel gain	Bandwidth decreases, throughput and performance increases.
H. Birkan Yilmaz et. al. 2015 [33]	Node with the best quality of received PU signal	Energy is saved, lifetime of SUs increases, accurate.
Ahmed S. B. Kozal et. al. 2014 [34]	Node with highest reporting channel SNR	Power and energy consumption reduces, faster detection.
Santi P. Maity et. al. 2015 [37]	Based on location, SNR and residual energy	Improved ROC, good performance gain.
Anal Paul et. al. 2016 [41]	Based on location, SNR and residual energy	Energy consumption is reduced.

III. CHALLENGES

The main challenges associated with the clustering are:

- *Cluster maintenance*: There is less literature available on cluster maintenance. The factors like migration of cluster head, cluster merging, cluster splitting, node joining and node leaving affects the channel availability at cluster head, which should be reconsidered, otherwise the packets would loss and the quality of service will degrade [42].
- *Tradeoff between various network performance parameters*: Sometimes, the tradeoff between the two factors is taken due to which other factors may get affected due to this. Hence, more work should be done towards this area and a balanced tradeoff should be there between network performance metrics [43].
- *Effect of clustering to cognitive radio schemes:* The clustering is done in regard to some particular objectives and applications but in regard to operation of CR as a whole, the effects of clustering on network parameters and QoS should be investigated [44].
- *Optimal cluster size*: In order to maintain a balance between the smaller and the larger cluster sized, and to avail the advantages of both, an optimal cluster size should be selected. The optimal cluster size may change with network scenarios as shown in [45].

IV. CONCLUSION AND FUTURE SCOPE

This article presented a review on various clustering schemes to form clusters in CR networks. Each one of them has its own objectives, advantages and disadvantages. There are number of selection metrics followed by each technique to locate the cluster head in every cluster. The clustering scheme can be selected according to the application and according to the desired characteristics. But to tackle a large number of CRs in a cognitive radio network not much work has been done, those who have done, had compromised to some of the factors like overhead, efficiency and Quality of service. Hence, a large number of CRs and the trade off between various factors is still a critical issue

In future, there is ample work in this field, addressing these challenges, like that of cluster maintenance, trade off between various factors, effect of clustering to cognitive radio schemes and the optimal cluster size. This article left a great foundation and ignited new research interests in this area.

REFERENCES

[1] D. Cabric, S. Mishra, R. Brodersen, "*Implementation issues in spectrum sensing for cognitive radios*", 38th Asilomar Conf. on Signals, Systems and Computers, USA, 2004.

[2] S Maleki, G Leus, "*Censored truncated sequential spectrum sensing for cognitive radio networks*", IEEE Journal on Selected Areas in Communications, Vol 31, Issue 3, pp. 364-378, 2013.

[3] N Reisi, M Ahmadian, V Jamali, S Salari, "*Cluster-based cooperative spectrum sensing over correlated log-normal channels with noise uncertainty in cognitive radio networks*", IET Communication, Vol 6, Issue 16, pp. 2725-2733, 2012.

[4] S. Althunibat, M. D. Renzo, F. Granelli, "*Optimizing the K-out-of-N rule for cooperative sensing in cognitive radio networks*", IEEE Global Communication Conference, USA, 2013.

[5] E.C.Y. Peh, Y.-C. Liang, Y.L. Guan, "*Optimization of cooperative sensing in cognitive radio networks*: *a sensing-throughput trade-off view"*, IEEE Transaction on Vehicular Technology, Vol. 58, Issue 9, pp. 5294-5299, 2009.

[6] W. Zhang, R. Mallik, K. Letaief, "*Optimization of cooperative spectrum sensing with energy detection in cognitive radio networks*", IEEE Transactions on Wireless Communications, Vol. 8, Issue 12, pp. 2009.

[7] Ian F. Akyildiz, B. F. Lo, R. Balakrishnan, "*Cooperative spectrum sensing in cognitive radio networks: A survey",* Vol. 4, Issue 1, pp. 40-62, Elsevier, 2010.

[8] K. A. Yau, N. Ramli, W. Hashim, H. Mohamad, *"Clustering algorithms for cognitive radio networks: A survey*", Journal of network and applications, Elsevier, Vol 45, pp. 79-95, 2014.

[9] Digham, F.F. Alouini, M.-S., Simon, M.K, "*On the energy detection of unknown signals over fading channels*", IEEE Trans. Commun., Vol. 55, Issue 1, pp. 21-24, 2007.

[10] N. Nguyen-Thanh, I. Koo, "*A cluster-based selective cooperative spectrum sensing scheme in cognitive radio*", EURASIP Journal on wireless Communications and Networking, 2013.

[11] Q Duong, VNQ Bao, H Tran, GC Alexandropoulos, HJ Zepernick, "*Effect of primary networks on the performance of spectrum sharing AF relaying*", IET Lett, Vol.48, Issue 1, pp. 25–27, 2012.

[12] N Nguyen-Thanh, I Koo, "*Log-likelihood ratio optimal quantizer for cooperative spectrum sensing in cognitive radio*", IEEE Commun. Lett., Vol.15, Issue 3, pp. 317–319, 2011.

[13] B Vo Nguyen Quoc, TQ Duong, D Benevides da Costa, GC Alexandropoulos, A Nallanathan, "*Cognitive amplify-and-forward relaying with best relay selection in non-identical Rayleigh fading*", IEEE COML, Vol. 17, Issue 3, pp. 475–478, 2013.

[14] Z Chair, PK Varshney, "*Optimal data fusion in multiple sensor detection systems*", IEEE Trans. Aerospace and Electronic Syst. AES, Vol. 22, Issue 1, pp. 98–101, 1986.

[15] Y. Jiao, P. Yin, I. Joe, "*Clustering scheme for cooperative spectrum*

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sensing in cognitive radio networks", IET Journals, Vol. 10, Issue 13, pp. 1590-1595, 2016.

[16] Chen, G. Wang, W. Peng, T, "*Agility improvements by censor-based cooperative spectrum sensing in cognitive radio networks*", Proc. Int. Conf. on Communication and Networking in China, August 2008.

[17] Li. H, Cheng, X., Li, K., et al., "*Robust collaborative spectrum sensing schemes for cognitive radio networks",* IEEE Trans. Parallel Distrib. Syst., Vol 25, Issue 8, pp. 2190-2200, 2014.

[18] Frey, B., Dueck, D., "*Clustering by passing messages between data points*", Science, Vol 315, Issue 5814, pp. 972-976, 2007.

[19] W. Kim, H. Jeon, SooyeolIm, H. Lee, "*Optimization of Multi-Cluster Multi-Group based cooperative sensing in cognitive radio networks*", IEEE Military communications conference, USA, 2010.

[20] O. Younis, and S. Fahmy, "*Distributed Clustering in Ad hoc Sensor Networks: A Hybrid Energy-Efficient Approach*,", Proc. of IEEE Annual Joint Conference of the Computer and Communications Societies (INFOCOM), China, 2004.

[21] F. A. Awin, E. Abdel-Raheem, M. Ahmadi, "*Optimization of multi-level hierarchical cluster-based spectrum sensing structure in cognitive radio networks*", Vol 36, pp. 15-25, Elsevier, 2014.

[22] A.C. Malady, C.R.C.M. da Silva,"*Clustering methods for distributed spectrum sensing in cognitive radio systems*", Mil. Commun. Conf. MILCOM, USA, 2008.

[23] Y. Wang, G. Nie, G. Li, C. Shi,"*Sensing-throughput tradeoff in cluster-based co-operative cognitive radio networks with a TDMA reporting frame structure",* Wirel. Pers. Commun., Vol 71, Issue 3, pp. 1795-1818, 2012.

[24] D. Oh, Y. Lee, "*Energy detection based spectrum sensing for sensing error minimization in cognitive radio networks*", J. Commun. Netw. Inf. Secur., Vol. 1, Issue 1, pp. 1-5, 2009.

[25] D.Calvetti, G.H. Golub, W.B. Gragg, L. Reichel,"*Computation of Gauss–Kronrod quadrature rules*", Math. Comput., 2000.

[26] G. Ganesan, "*Cooperative spectrum sensing in cognitive radio networks",* First IEEE Int. Symp. New Front. Dyn. Spectr. Access Networks, USA, 2005.

[27] Balaji V, T. Nagendra, C. Hota, G Raghurama, "*Cooperative spectrum sensing in cognitive radio: An Archetypal Clustering Approach"*, IEEE WISPNET conference, 2016.

[28] A. Cutler, L. Breiman, "*Archetypal analysis*," Technometrics, 1994.

[29] Balaji V, X. Fernando, "*Approach for cluster-based spectrum sensing over band-limited reporting channels*", IET Communications, Vol 6, Issue 11, pp. 1466-1474, 2012.

[30] Bao, L., Carcia-Luna-Aceves, J.J, "*Topology management in ad hoc networks*". Proc. Int. Symp. on Mobile Ad Hoc Networking and Computing, 2003.

[31] Amis, A., Prakash, R., Vuong, T., Huynh, D.T, "*Max-Min D-cluster formation in wireless ad hoc networks*", Proc. IEEE Int. Conf. on Computer Communications, 2000.

[32] Krishna, P., Vaidya, N., Chatterjee, M., Pradhan, D., "*A cluster-based approach for routing in dynamic networks*", Comput. Commun. Rev., Vol 27, Issue 2, pp. 49-64, 1997.

[33] Aki f Cem Heren, H. Birkan Yilmaz, Tuna Tugcu, "*Energy efficient MAC protocol for cluster formation in mobile cooperative spectrum sensing*", IEEE Wireless Communications and Networking Conference, USA, 2015.

[34] Ahmed S. B. Kozal, M. Merabti, F. Bouhafs, "*Energy-Efficient Multi-hop Clustering Scheme for Cooperative Spectrum Sensing in Cognitive Radio Networks*", IEEE 11th Consumer Communications and Networking Conference, USA, 2014.

[35] W. B. Heinzelman, *et al.*, "*An application-specific protocol architecture for wireless micro sensor networks*", IEEE Transactions on Wireless Communications, Vol 1, Issue 4, pp. 660-670, 2002.

[36] T. Rasheed, A. Rashdi, A. N. Akhtar, "*A Cluster Based Cooperative Technique for Spectrum Sensing using Rely Factor*", 12th International Bhurban Conference on Applied Sciences and Technology, Pakistan, 2015.

[37] Santi P. Maity, Subhankar Chatterjee, Tamaghna Acharya, "*On optimal fuzzy c-means clustering for energy efficient cooperative spectrum sensing in cognitive radio networks*", Elsevier journal on DSP, Vol 49, Issue 1, pp. 104-115, 2015.

[38] J.C. Bezdek, "*Pattern Recognition with Fuzzy Objective Function Algorithms*", Plenum Press, New York, 1981.

[39] S. Chatterjee, A. Banerjee, T. Acharya, S.P. Maity, "*Fuzzy C-means clustering in energy detection for cooperative spectrum sensing in cognitive radio system*", 8th International Workshop on Multiple Access Communications, Switzerland, 2014.

[40] S. Huang, H. Chen, Y. Zhang, F. Zhao, "*Energy-efficient cooperative spectrum sensing with amplify-and-forward relaying*", IEEE Commun., Vol 16, Issue 4, pp. 450-454, 2012.

[41] Anal Paul, Santi P. Maity, "*Kernel fuzzy c-means clustering on energy detection based cooperative spectrum sensing*", Elsevier journal on digital communication and networks, Vol 2, Issue 4, pp. 196-205, 2016.

[42] Sharma P, Abrol V, "*Optimized cluster head selection & rotation for cooperative spectrum sensing in cognitive radio networks*", Proceedings of 10th inter- national conference on wireless and optical communications networks (WOCN'13), Bhopal, India, 2013.

[43] Kim M-R, "*Distributed coordination protocol for common control channel selection in multichannel ad-hoc cognitive radio networks*", Proceedings of the IEEE conference on wireless and mobile computing, networking and communications (WIMOB'09), Marrakech, Morocco, 2009.

[44] Guo C, Peng T, Xu S, Wang H, Wang W, "*Cooperative spectrum sensing with cluster- based architecture in cognitive radio networks"*, Proceedings of the IEEE 69th vehicular technology conference (VTC Spring'09), Barcelona, Spain; 2009.

[45] Huang X-L, Wang G, Hu F, Kumar S., "*Stability–capacity–adaptive routing for high- mobility multi-hop cognitive radio networks*", IEEE Transaction on Vehicular Technology, Vol 60, Issue 6, pp. 2714-2729, 2011.

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