RED: Resource Management in Remote Inaccessible Terrains by Exploitation of DTN Contacts

Rahul Johari and Kalpana Gupta

***Abstract*—In areas characterized by long duration partitioning ranging from few minutes to few hours, routing is a common problem. Various routing Schemes, both deterministic and Stochastic have been proposed in literature. Some of the routing schemes are built around different types of Delay Tolerant Network Routing Contacts viz Persistent Contact, Opportunistic Contact, Scheduled Contact, Predicted Contact and On-Demand Contact (POSOP) whereas some are not. But it appears majority of these routing schemes are more idealistic in nature and fail to touch the human lives by solving their day to day problem. It can said with full conviction because when extensive survey was carried out by exploring the mountainous track and natural geographical terrain of Uttarakhand region(state in republic of India) it was found that villagers of remote villages and hamlets like Barkot, Harsil, Chamoli etc., were suffering from the acute shortage of quality drinking water and urgent medical care. Now can DTN touch this aspect of human lives and provide the solution to their problem? , the answer is not easy to come by. But in this paper we study this problem, explores the application of proposed POSOP Contacts and present our work through mobile application developed through MobiOne Design Studio.**

***Index Terms*—DTN, contacts, routing, MobiOne Design.**

I. Introduction

Delay tolerant network [1] are those networks which are characterized by frequent delays incurred due to lack of end to end communication path between the sender and receiver .The word Delay tolerant itself signifies that ultimate goal of DTN is the eventual delivery of the message, in spite of the intermittent delay caused due to natural/environmental factors or man-made conditions. Delay tolerant network consists of interconnected mobile devices termed as DTN nodes. The topology changes dynamically due the constant movement of the nodes. These intermediate mobile nodes buffer the message until a new path is discovered or a broken path is repaired and re-established.

II. General Applications of DTN

Various researchers over a period of time have explored various applications of routing in DTN such as:

1) InterPlaNetary(IPN) Internet project [2].
2) Whizzy digital courier service which provides asynchronous (disconnected) Internet access to schools in remote villages of South Africa [3].
3) A scenario where a hypothetical village is being served by digital courier service, a wired dial-up Internet connection and a store and forward LEO satellite. Route selection through any one of them depends upon the variety of factors including message source and destination, message size, time of request, available connections or other factors like cost and delay etc. [3].
4) Transmission of information/message during mission critical operations for instance natural disasters like earthquake, floods and Cyclone etc.
5) Resource discovery : Where in people may want to find a determined service without knowing their accurate locations, such as searching for historical monument to be visited in a city; or searching for ATM in a metro town or city or simply searching for a vacant parking slot in the shopping mall/plaza.
6) Long distance education: Where in Asynchronous Internet access or VSAT can be used to reach out to school(s) or college(s) in remote villages with state transport buses acting as ferries carrying the resource material.
7) Post Office delivery model where in Post man collects/delivers the Ordinary Post/Registered Post Letter by visiting remote villages using cycle/motorbike as ferry, more like a typical DakNet Project [4].
8) Battle fields (a soldier may want to convey the battle field information to anyone of the command centers or control room of his unit).

III. Background

Since the last decade DTN has drawn considerable amount of attention from the researchers due to the problems faced by loss of end to end connectivity between the source and destination. Possible reasons could be consistent bad weather condition in certain areas or happening of a natural calamity like occurrence of earthquake, cyclone, flash foods or heavy rains threatening the very existence of flora and fauna of the region. As a result these regions suffer from total blackout and communication lines get snapped off. DTN could be the answer for these regions where networks break down and nodes experience intermittent connection and can be boon in providing relief and rescue operations to the affected persons. RFC of DTN [1] describes five types of contacts namely, Persistent, On-demand, Intermittent-Scheduled, Intermittent-Opportunistic and Intermittent-Predicted (POSOP) that may exist in a DTN. Routing schemes [5]-[20] exploit one or two such contacts to route the messages. To the best of our knowledge none of the routing schemes proposed in literature exploits all the five types of contacts.

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IV. Related Work

Epidemic routing [10] is one of the earliest approach proposed for DTN. Epidemic routing uses pair wise encounter to deliver the message. This approach exploits opportunistic contacts to forward a message. The approach results in high message delivery ratio but also generates huge message traffic. The approach is not suitable where buffer space, processing power and battery level of relay node is constrained. Also this routing scheme overloads the network with redundant messages and is therefore not suited for sparsely connected networks. The problem of message traffic was overcome by using probabilistic approaches and controlled flooding [13]. Both these techniques exploit only opportunistic contacts for message forwarding.

One of the greatest challenges is limited buffering space of a node as it has to store message all the time. The classes of routing algorithms these days are based on various day to day life activities such as probability, social grouping etc. The probability of a node to deliver a message to the destination may vary from time to time. So the strength of their contact frequency with base station is determining factor in choosing the node of higher probability of delivering the message .In social grouping every node remains in touch with some other node and hence social groups are formed based on their interaction with other nodes. Dynamic social grouping makes use of both probabilistic and social group formation for routing. Since messages are stored in the buffer of intermediate node, therefore security of the message is also an important criterion.

An approach proposed by Sushant Jain *et al*. [3], exploits contact history for predicting the futuristic contact information of the node and chooses the shortest path for routing the messages. The success of this approach is based on existence and correctness of nodes mobility data

Social groups based routing schemes [5], [7], [9], [11], [15] uses the mobility pattern of nodes for choosing the best opportunistic contacts.

Some of the routing approaches have exploited the idea of scheduled movement of special nodes such as ferry, data mules [21], [22] etc. The approach is able to utilize the existence of the availability of scheduled contact only. DSG-PC [12], a routing approach, exploits both the opportunistic and scheduled contact for routing the messages. In this approach, a node decides whether to forward a message using an opportunistic contact or wait for an arrival of a scheduled contact on the basis of message ttl (time to live). Scheduled carrier has been shown to add a delay as it follows a fixed path and contacts a node at fixed time. In [14] authors showcase the designing of DTN for mountainous region exploiting all the five type of contacts.

The wireless network has been shown to be an effective but challenging communication mechanism in rural areas. In [23], [24] the authors present two projects in India in which they have used IEEE 802.11 (Wi-Fi) as a cost-effective technology to provide wireless access to rural areas: 1) Digital Gangetic Plains (DGP), project was initiated in 2002 at the Indian Institute of Technology, Kanpur (IITK), Uttar Pradesh and 2) Ashwini, project was a network deployment effort by the Byrraju Foundation, to provide broadband access and services to a collection of villages in the West Godavari district of Andhra Pradesh, India. Using these projects authors discusses five important aspects in the use of Wi-Fi for rural connectivity: (a) network planning and deployment, (b) network protocols, (c) network management and operations, (d) power savings, and (e) applications and services. In [24] authors observe that providing connectivity to under-serviced and inaccessible rural areas comes with a unique set of challenges such as the high cost of establishing infrastructure like: installing equipment, lack of reliable power, skill shortages and high cost of providing Internet connectivity which is mostly satellite based. The authors studies the deployments of low-cost wireless rural networks in South Africa and Zambia and demonstrated very encouraging results.

In [25], [26] author says that water scarcity can be exhibited both in absolute or volumetric terms. But do most analyses of scarcity focus on how the problem of scarcity is constructed, the need to disaggregate users and their entitlements and the imperative to look at the politics of distribution and technology choice within a frame of political economy? The paper draws on a wide range of conceptual approaches such as political ecology, common property resource theory and post-institutional approaches to highlight that scarcity is not a natural condition. Instead, it is usually socially mediated and the result of socio-political and institutional processes.

V. Problem Scenario

Uttarakhand is a state in Republic of India. The state is situated in foothills of Himalayan range, with most of the villages situated in hilly area. Total area of Uttarakhand is 51,125 sq. km whereas population density of Uttarakhand is 189 per sq. km which is lower than national average 382 per sq. km [27]. There are two divisions namely Kumaun region and Garhwal region comprising of 13 districts and 15828 villages/towns in the state [28]. The major sources of drinking water in hills are small rivers and rivulets locally called gadhera. For traping these sources a masonry walls of cement concrete are constructed across the rivulets, which generally get damaged or washed away during heavy rains causing interruption to water supply scheme. To provide safe and quality drinking water to the villagers of these 15828 villages is the most challenging task and this is where Delay Tolerant Network steps in to solve their daily problem of getting potable drinking water.

VI. Motivation

The health status of the needy and underprivileged people in our society is very bad, more so in slums and rural area(s) where infrastructure is lacking and resources are very limited as villagers have to walk miles to fetch a bucket of water for drinking and washing. All this motivated, to initiate the micro level work in this direction by proposing DTN contact(s) as reliable - intermittent - partitioned - sparse network points of data dissemination so that potable drinking water and timely medical services can be provided to the villagers and thousands of lives every year can be saved.

The inspiration was also drawn from the three steps initiated by the Government of India, in the past few years.

Firstly, in its endeavor to provide best and latest medical facilities to its rural population, started National Rural Health Mission (NRHM) [29], which was launched in the year 2005 to strengthen the rural public health system. All these efforts are being carried out so as to provide effective health care to the rural populace throughout the country with special focus on the States and Union Territories (UTs), which have weak public health indicators and/or weak infrastructure. Secondly, India like rest of the world has witnessed telecom revolution which is evident from latest statistics revealed in TRAI [30] report which states that the rural wireless subscribers increased from 331.60 million at the end of December 2012 to 342.50 million at the end of March 2013.Subscription in Urban Areas decreased from 556.96 million at the end of December 2012 to 548.80 million at the end of March 2013 and the Urban Tele-density declined from 149.90 to 146.96 during the same quarter. Whereas rural subscription increased from 338.54 million to 349.22 million and the rural tele-density increased from 39.85 to 41.02 during the quarter January-March 2013. The year-on-year (Y-O-Y) growth rate of Rural and Urban Tele-density from March 2012 to March 2013 is 4.57% and -13.32% respectively. Thirdly, in order to quench the thirst of its burgeoning population Government of India not only dedicated the year 2013 as Water Conservation Year but has also formulated a scheme called Water Policy and Action Plan for India 2020: An Alternative [25].

VII. Design Consideration of Routing Algorithms

While designing the routing protocols we need to consider parameters that can incorporate the long delays associated with DTN. The designed protocols must support any cast or multicast messages while forwarding and routing. Limitations of network resources such as buffers space and energy, dynamic changing topology, cost, reliability, security are major challenges in this emerging area of routing.

A. Successful Routing of Messages

The foremost criteria in designing an algorithm in DTN is the eventual delivery of the message. Other factors are of importance only after a routing protocol delivers the message successfully to the destination node.

B. Buffer Energy and Size

The buffers are the storehouses for the messages therefore the databases with enough memory support are installed. Although this is a hardware issue but use of logical structure for storage may prevent redundancy and hence can save memory .The buffers need to have longer battery life to be in active state all the time.

C. Reliability

The algorithms support acknowledgement message which are sent from destination to source on successful delivery of a message. This way the source is updated about status of transmitted messages and hence avoids unnecessarily retransmissions.

D. Data Packet Dropping

Even though delay is supported in such networks still we should reduce the delays to have a better performance. A large amount of buffer space and a number of message replacement algorithm, queue the message based on factors such as priority, resources held, age of message, timestamp etc. Data packet dropping rate can be controlled by taking the above measures.

E. Security

For applications designed for military operation DTN provides a new outlook for preserving confidential information messages being getting lost in remotely inhabited areas which suffer from frequent communication failure due to loss of end to end connectivity. Use of complex cryptographic algorithms and authentication checks implemented at various steps prevent the messages from attackers and spies.

VIII. Applicability of DTN Contacts in Village Scenario

Routing Schemes both Deterministic and Stochastic in Delay Tolerant Network fails to fully exploit the varied type of DTN contacts viz. Scheduled Contact, On-Demand Contact, Predicted or Probabilistic Contact, Persistent Contact and Opportunistic Contact. While travelling through the some of the villages belonging to 13 districts in the state of Uttarakhand, we came across many issues that touches the life of common villager such as proper hygienic sanitation condition, public distribution system (PDS) for the essential supply and distribution of sugar, wheat and pulses at reasonable cost, implementation of mid-day meal scheme in primary and middle schools and various sub-issues on how to increase the production related to horticulture, agriculture, diaries and fisheries *et al.* wherein villagers have to jostle these problems on day to day basis to make their ends meet. But the most challenging issues was the inaccessibility of quality drinking water in the number of remote towns and villages either due to the ineffective water distribution framework as a result water is unable to reach to the hundreds of villagers or due to remote inaccessibility of the villages owing to their geographical location with no proper road connectivity to nearest town.

We now present how the different types of contact can be exploited in the DTN for the efficient transmission and distribution of the messages which are going to be generated by the villagers or Village Head/Sarpanch using their Stationary or mobile DTN nodes to communicate with the Municipal Corporation regarding the supply and distribution of water in the village. In this paper a sincere effort to map the DTN Contacts (as specified in the RFC) to the actual problem of Water distribution framework existing in the towns and villages of the Uttarakhand state has been made. Accordingly, the messages thus generated are classified as DTN messages into: Bulk (Low priority messages), Normal (Medium Priority messages) or Expedited (High Priority) messages.

A. Persistent Contact

In Persistent Contact a direct water pipeline is laid down right from the source (Municipal water overhead tank) to the different households of the village so there is no urgent need of any message generation from the source. After receiving the water supply the village head or Sarpanch generates a message (Bulk type) informing the municipal corporation

regarding the supply of water.

B. Scheduled Contact

The scheduled contact can be enacted and visualized in both the scenarios:

Scenario A: If there exists a scheduled contact then it species the time of day at which the water is going to be supplied by the municipal corporation so that the villagers can receive the water supply in their house hold at the designated day/time. After the receiving the water supply the village head generates a message (Bulk type) informing the municipal corporation regarding the supply of water.

Scenario B: If the village is suffering from acute shortage of water and there is no municipal supply of water then the Village Head known as Sarpanch of the gram Sabha/village generates a message (Expedited type) for the municipal corporation to provide the water tanker. The Message would be transmitted by the village Head through his DTN Node for the destination DTN Node installed at the Municipal Corporation office asking it for the dispatch of the Water tanker which would visits the village every day or every alternate day at the scheduled time say in the morning at 11 am or in evening at 4 pm, so that the villagers can receive good quality water.

C. Opportunistic Contact

The Opportunistic contact too be enacted and visualized in following two scenarios:

Scenario A: In such a contact there is no fixed time when the water would be supplied by the municipal corporation to the villages, as a result the villagers are always in the ready and/or alert mode throughout the day to receive quality drinking water from the municipal corporation. No message generation is needed in such a situation.

Scenario B: In such a contact if the water tankers is visiting a particular village 'A' on the request of the sarpanch, and there exists a neighboring village 'B' then the villagers of this village seizes this opportunity as the village Head through his DTN Node dispatches the message(Normal type) for the destination DTN Node installed at the Municipal Corporation Office asking it the permission may be granted to the villagers to draw few kiloliters of Water from the Water tanker for the needy villagers.

D. On-Demand Contact

In such a contact if the water pipelines get burst up due to digging or soil erosion or landslides then the village reels under acute shortage of water, with no supply of municipal water for days together. To extricate the villagers, the sarpanch of the gram Sabha generates a message (Expedited type) from his DTN node asking the municipal corporation to provide water tanker to the affected village, until the water pipelines are repaired and the situation is normalized. In such situations the water tanker visits the village at pre-determined time of 12 noon every day, so that the villagers can receive the quality drinking water.

E. Probabilistic Contact/Predicted Contact

In such a contact if the water supply to a village is non-continuous and erratic, then the villagers are never sure when they would receive the water supply, so they just observe and remember the timings of the water they had received from the municipal corporation in the last couple of days, based on which they compute the probability of time when municipal corporation will supply water to them and this calculation is done on almost day to day basis. Message generation in such a case would be of Normal type.

IX. Experimental Setup

The mobile Application to be deployed on the DTN nodes has been designed using the MobiOne Software [31]. The snapshot of the Mobile App designed for has been depicted in Fig. 3. For the purpose of empirical study three villages viz. Adhar Muafi [32], Adhuriya [33] and Adhelisunar [34] of Almora district with population size of less than 1000 and three villages viz. Aamkheri [35], Ajitpur Mustakam [36] and Alwalpur [37] of Hardwar district with population size greater than 1000 were considered. Fig. 1 and Fig. 2 shows the comparison between the chosen villages on the parameters such as: number of household, population size and messages generated. The message generated would be equal to the number of households in a village.

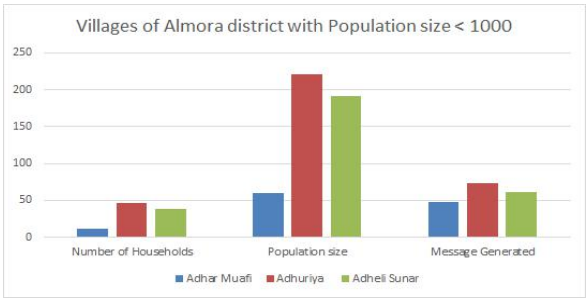

Fig. 1. Villages of Almora district.

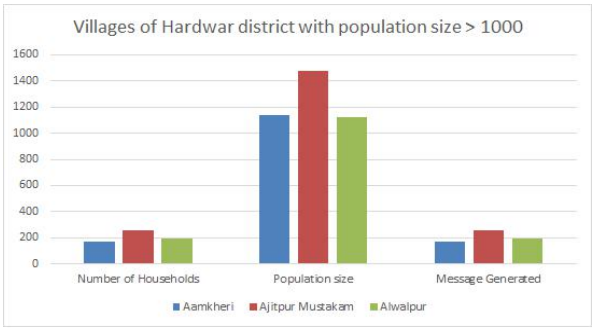

Fig. 2. Villages of Hardwar district.

Fig. 3. Mobile application on iPhone.

X. Conclusion and Future Work

The current work takes into account three villages each of the Almora and Hardwar district but we would expand the work to cover more districts of Uttarakhand region. We would extend our work by taking the grant from the Non-Governmental Organizations (NGO's) or Government Agencies like Department of Science and Technology so that the funds are available to carry out the deployment of real time DTN nodes in the Uttarakhand region spanning across all the districts to effectively establish DTN enabled Wireless network.

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References

[1] V. Cerf, S. Burleigh, A. Hooke, L. Torgerson, R. Durst, K. Scott, K. Fall, and H. Weiss, "Delay-tolerant networking architecture," *IETF (Informational)*, RFC 4838, April 2007.
[2] S. Burleigh, A. Hooke, L. Torgerson, K. Fall, V. Cerf, B. Durst, K. Scott, and H. Weiss, "Delay-tolerant networking: An approach to inter-planetary internet," *IEEE Communications Magazine*, vol. 41, no. 6, pp.128-136, 2003.
[3] S. Jain, K. Fall, and R. Patra, "Routing in a delay tolerant network," *SIGCOMM Comput. Commun. Rev.*, vol. 34, no. 4, pp.145-158, August 2004.
[4] A. Pentland, R. Fletcher, and A. H. Daknet, "Rethinking connectivity in developing nations," *Computer*, vol. 37, no. 1, pp. 78-83, 2004.
[5] R. Cabaniss, S. Madria, G. Rush, A. Trotta, and S. S. Vulli, "Dynamic social grouping based routing in a mobile ad-hoc network," in *Proc. of the 2010 Eleventh International Conference on Mobile Data Management (MDM '10)*, pp. 295-296, 2010.
[6] G. Chen, D. Kotz, *et al.* "A survey of context-aware mobile computing research," Technical Report TR2000-381, Dept. of Computer Science, Dartmouth College, 2000.
[7] P. Costa, C. Mascolo, M. Musolesi, and G. P. Picco, "Socially-aware routing for publish-subscribe in delay-tolerant mobile ad hoc networks," *IEEE Journal on Selected Areas in Communications*, vol. 26, no. 5, pp. 748-760, 2008.
[8] R. Johari and S. Dhama, "Routing protocols in delay tolerant networks: Application-oriented survey," in *Proc. of International Conference on Wireless Communications, Networking and Applications (WCNA 2014)*, pp. 1255-1267, 2016.
[9] E. M. Daly and M. Haahr, "Social network analysis for routing in disconnected delay-tolerant manets," in *Proc. of the 8th ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc '07)*, pp. 32-40, 2007.
[10] A. Vahdat, D. Becker, *et al.* "Epidemic routing for partially connected ad hoc networks," Technical Report CS-200006, 2000.
[11] H. Pan, J. Crowcroft, and E. Yoneki, "Bubble rap: social-based forwarding in delay tolerant networks," in *Proc. of the 9th ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc '08)*, pp. 241-250, 2008.
[12] R. Johari, N. Gupta, and S. Aneja, "Dsg-PC: Dynamic social grouping based routing for non-uniform buffer capacities in DTN supported with periodic carriers," *QSHINE*, pp. 1-15, 2013.
[13] A. Lindgren, A. Doria, and O. Schelen, "Probabilistic routing in intermittently connected networks," *SIGMOBILE Mob. Comput. Commun. Rev.*, vol. 7,no. 3, pp. 19- 20, July 2003.
[14] R. Johari, N. Gupta, and S. Aneja, "Posop routing algorithm: A DTN routing scheme for information connectivity of health centres in hilly state of north India," *International Journal of Distributed Sensor Networks*, June 2015.
[15] L. McNamara, C. Mascolo, and L. Capra, "Media sharing based on colocation prediction in urban transport," in *Proc. of the 14th ACM International Conference on Mobile Computing and Networking (MobiCom '08)*, pp. 58-69, 2008.
[16] S. C. Nelson, M. Bakht, R. Kravets, and A. F. Harris, "III. En-counter: Based routing in DTNs," *SIGMOBILE Mob. Comput. Commun. Rev.*, vol. 13, no. 1, pp. 56-59, June 2009.
[17] Fatimah, Afreen, and R. Johari, "Part: Performance analysis of routing techniques in delay tolerant network," in *Proc. of the International Conference on Internet of Things and Cloud Computing*, p. 76, 2016.
[18] K. Fall and S. Farrell, "DTN: An architectural retrospective," *IEEE Journal on Selected Areas in Communications*, vol. 26, no. 5, pp. 828-836, 2008.
[19] Y. Wang and H. Wu, "Delay/fault-tolerant mobile sensor network (DFT-MSN): A new paradigm for pervasive information gathering," *IEEE Transactions on Mobile Computing*, vol. 6, no. 9, pp.1021-1034, Sep. 2007.
[20] Singh, Shilpy, R. Johari, and M. Kaur, "ART: Analysis of routing techniques in delay tolerant network," in *Proc. of International Conference on Electrical, Electronics and Optimization Techniques (ICEEOT)*, pp. 2537-2542, 2016.
[21] W. Zhao, M. Ammar, and E. Zegura, "A message ferrying approach for data delivery in sparse mobile ad hoc networks," in *Proc. of the 5th ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc '04)*, pp. 187-198, 2004.
[22] R. C. Shah, S. Roy, S. Jain, and W. Brunette, "Data mules: Modeling and analysis of a three-tier architecture for sparse sensor networks," *Ad Hoc Networks*, vol. 1, no. 2-3, pp. 215-233, 2003.
[23] B. Raman and K. Chebrolu, "Experiences in using Wi-Fi for rural internet in India," IEEE *Communications Magazine*, vol. 45, no. 1, pp. 104-110, 2007.
[24] D. L. Johnson and K. Roux, "Building rural wireless networks: Lessons learnt and future directions," in *Proc. of the 2008 ACM Workrshop on Wireless Networks and Systems for Developing Regions*, pp. 17-22, 2008.
[25] G. N. Kathpalia and R. Kapoor, *Water Policy and Action Plan for India 2020: An Alternative*, 2002.
[26] L. Mehta, "Whose scarcity? Whose property? The case of water in western India," *Land Use Policy*, vol. 24, no. 4, pp. 654-663, 2007.
[27] Wikipedia-Uttarakhand. *Wikipedia, the Free Encyclopedia*. [Online]. Available: https://en.wikipedia.org/wiki/Uttarakhand
[28] *Uttarakhand Population Census Data*, 2011.
[29] *National Health Mission*, 2013.
[30] *The Indian Telecom Services Performance Indicators January-March*, 2013.
[31] *Mobionesite*, 2018.
[32] *Adhar Muafi Village of Almora*, 2013.
[33] *Adhuriya Village of Almora*, 2018.
[34] *Adhelisunar Village of Almora*, 2013.
[35] *Aamkheri Village of Hardwar District*, 2018.
[36] *Ajitpur Mustakam Village of Hardwar District*, 2018.
[37] *Alwalpur Village of Hardwar District*, 2018.

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